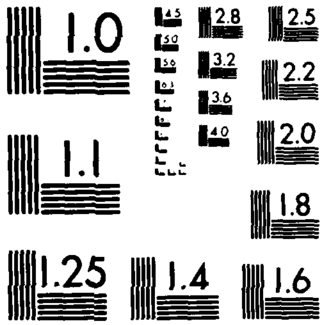
AD-A151 617 USER'S GUIDE FOR CONCRETE STRENGTH INVESTIGATION AND DESIGN (CSTR)(U) ARMY ENGINEER WATERWAYS EXPERIMENT STATION VICKSBURG MS C C HAMBY ET AL. SEP 84 1/2

UNCLASSIFIED WES-INSTRUCTION-K-84-9 F/G 11/2 NL


1.0
2.8
2.5
3.2
2.2
3.6
4.0
2.0
1.1
1.8
1.25
1.4
1.6

(4)

US Army Corps
of Engineers

AD-A151 617

INSTRUCTION REPORT K-84-9

USER'S GUIDE FOR CONCRETE STRENGTH INVESTIGATION AND DESIGN (CSTR)

by

Clifton C. Hamby and William A. Price III

Automation Technology Center

DEPARTMENT OF THE ARMY
Waterways Experiment Station, Corps of Engineers
PO Box 631
Vicksburg, Mississippi 39180-0631

September 1984

Final Report

Approved for public release; distribution unlimited

AUTOMATION TECHNOLOGY CENTER

Prepared for
US Army Engineer Division
Lower Mississippi Valley
Vicksburg, Mississippi 39180-0080

PROGRAM INFORMATION

Description of Program

CSTR, called X0066 in the Conversationally Oriented Real-Time Program-Generating System (CORPS) library, is a general-purpose computer program for the strength theory analysis or design of reinforced concrete beams or columns, in accordance with ETL 1110-2-265 for hydraulic structures. It is intended to be an easy-to-use program.

Coding and Data Format

CSTR is written in FORTRAN and is operational on the following systems:

a. WES and Division office Honeywell DPS/8.

b. District office Harris 500.

c. Cybernet Computer Service's CDC CYBER 175.

Data must be in a prepared data file with line numbers. Output comes directly back to the terminal. The terminal must be a Tektronix 4014 if graphics display is wanted.

How to Use CSTR

Directions for accessing the program on each of the three systems is provided below. It is assumed that the user can sign on the appropriate system before attempting to use CSTR. In the example initiation of execution commands below, all user responses are underlined, and each should be followed by a carriage return.

Honeywell Systems

After the user has signed on the system, the system command FORT brings the user to the level to execute the program. Next, the user issues the run command

```
RUN WESLIB/CORPS/XØØ66,R
```

to initiate execution of the program. The program is then run as described in this user's guide. The data file should be prepared prior to issuing the RUN command. An example initiation of execution is as follows, assuming a data file has previously been prepared:

```
HIS TIMESHARING ON Ø3/Ø4/81 AT 13.3Ø1 CHANNEL 5647
USER ID - RØKACASECON
PASSWORD - WHERE/ARE/YOU?
*FORT
*RUN WESLIB/CORPS/XØØ66,R
```

CYBERNET System

The log-on procedure is followed by a call to the CORPS procedure file

OLD,CORPS/UN=CECELB

to access the CORPS library. The file name of the program is used in the command

BEGIN,,CORPS,XØØ66

to initiate execution of the program. An example is:

```
84/12/Ø5.  16.41.ØØ.  AC2F5DA
EASTERN CYBERNET CENTER SN9Ø4 NOS     1.4/531.669/2ØAD
FAMILY:  KOE
USER NAME:  CEROXX
PASSWORD -
XXXXXXXX
TERMINAL:  23, NAMIAF
RECOVER/CHARGE:  CHARGE,CEROEGC,CEROXX
$CHARGE
12.49.07.  WARNING

11/29 FOR IMPORTANT INFO TYPE EXPLAIN,WARNING.
OLD,CORPS/UN=CECELB
/BEGIN,,CORPS,XØØ66
```

Harris 500 System

The log-on procedure is followed by a call to the program executable file, with the user typing the asterisk and file description

*CORPS,XØØ66

to initiate execution of the program. An example is

```
"ACOE-ABLESVILLE (H500 V3.1)"
ENTER SIGN-ON
1234ABC,STRUCT

**GOOD MORNING STRUCTURES, IT'S 7 DEC 84 Ø8:33:12
AED HARRIS 500 OPERATING HOURS 0700-1800 M-S
*CORPS,XØØ66
```

How to Use CORPS

The CORPS system contains many other useful programs which may be catalogued from CORPS by use of the LIST command. The execute command for CORPS on Honeywell systems is:

```
RUN WESLIB/CORPS/CORPS,R
ENTER COMMAND (HELP,LIST,BRIEF,MESSAGE,EXECUTE, OR STOP)
*?LIST
```

on the Cybernet system, the commands are:

```
OLD,CORPS/UN=CECELB
CALL,CORPS
ENTER COMMAND (HELP,LIST,BRIEF,MESSAGE,EXECUTE, OR STOP)
*?LIST
```

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (*When Data Entered*)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER Instruction Report K-84-9	2. GOVT ACCESSION NO. A151617	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (*and Subtitle*) USER'S GUIDE FOR CONCRETE STRENGTH INVESTIGATION AND DESIGN (CSTR)		5. TYPE OF REPORT & PERIOD COVERED Final report
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Clifton C. Hamby William A. Price III		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS US Army Engineer Waterways Experiment Station Automation Technology Center PO Box 631, Vicksburg, Mississippi 39180-0631		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS US Army Engineer Division Lower Mississippi Valley Vicksburg, Mississippi 39180-0080		12. REPORT DATE September 1984
		13. NUMBER OF PAGES 94
14. MONITORING AGENCY NAME & ADDRESS(*if different from Controlling Office*)		15. SECURITY CLASS. (*of this report*) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (*of this Report*)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (*of the abstract entered in Block 20, if different from Report*)

18. SUPPLEMENTARY NOTES

Available from National Technical Information Service, 5285 Port Royal Road, Springfield, Virginia 22161.

19. KEY WORDS (*Continue on reverse side if necessary and identify by block number*)

Computer Aided Design, ~~(WES)~~
Concrete Products--Evaluation, ~~(LC)~~
CSTR (Computer Program), ~~(LC)~~
Hydraulic Structures~~--Computer Programs (LC)~~
Fortran, Mechanical Drawings,

20. ABSTRACT (*Continue on reverse side if necessary and identify by block number*)

Program CSTR is versatile in that its capabilities extend from design of new concrete hydraulic structures to investigation of already existing designs. Its analysis is based on the rectangular stress block described in ETL 1110-2-265.

The design procedure is computer-aided rather than automatic and computes the minimum reinforcement required for a given width and depth, and displays

(Continued)

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (*When Data Entered*)

20. ABSTRACT (Continued).

the resulting interaction diagram. The program also computes and prints the minimum effective depth of a given section which satisfies strength requirements and steel ratio requirements without compressive reinforcement.

The investigation procedure shows interaction diagrams and calculates compliance with ductile failure criteria.

[illegible] / keywords included: → 1p.

Preface

The computer program described in this user's guide was developed as a part of the work by the Engineering Applications Group (EAG), Automation Technology Center (ATC), US Army Engineer Waterways Experiment Station (WES), in support of the Computer-Aided Structural Design (CASD) Committee of the US Army Engineer Division, Lower Mississippi Valley (LMVD). Funds were provided by LMVD as part of WES ATC engineering analysis support.

Mr. V. M. Agostinelli of LMVD was chairman of the CASD Committee during this work. The theoretical development to implement Engineer Technical Letter (ETL) 1110-2-265 was performed by Mr. Clifton C. Hamby, formerly of the EAG and presently of the US Army Engineer District, Vicksburg (LMK). Programming was by Mr. Hamby, assisted by Mr. William A. Price III, Chief, EAG. Program verification calculations were by Mr. Pete Oddi, LMK. The work was performed under the direction of Mr. Paul K. Senter, Civil Engineer, with overall supervision by Dr. N. Radhakrishnan, Chief, ATC.

The Commanders and Directors of WES during the work and preparation of this report were COL Tilford C. Creel, CE, and COL Robert C. Lee, CE. Technical Director was Mr. F. R. Brown.

Contents

Conversion Factors, US Customary (Non-SI) to Metric (SI) Units of Measurement

US customary (Non-SI) units of measurement used in this report can be converted to metric (SI) units as follows:

Multiply	By	To Obtain
feet	0.3048	metres
inches	2.540	centimetres
kips	112.9848	newton-metres
kips-feet	138.255	kilogram-metres
kips per square inch	6894.757	kilopascals
pounds per square inch	6.894757	kilopascals
square inches	6.4516	square centimetres

USER'S GUIDE FOR CONCRETE STRENGTH INVESTIGATION AND DESIGN (CSTR)

Introduction

1. The US Army Corps of Engineers introduced a strength design procedure in 1981 for use in the design of hydraulic structures. This design procedure was published in Engineer Technical Letter (ETL) 1110-2-265, referred to hereafter as ETL-265. A computer program, Program CSTR, has been developed by the US Army Engineer Waterways Experiment Station Automation Technology Center that can be used for design of or investigation of concrete members by the strength design method. Program CSTR ("C-STAR") is in compliance with the guidance contained in ETL-265. It utilizes a generalized equation to obtain the axial force and moment capacity of any rectangular concrete section, reinforced or not, in any pattern (paragraph 13). This approach allows for solution of a wide variety of problems and loadings, such as singly or doubly reinforced beams, columns, beam-columns, tension members, etc.

Assumptions

2. The fundamental assumptions used in the development of program CSTR are summarized below. More details on these assumptions are included in paragraphs 10 through 16. Figure 1 is provided to further complement the following discussions.

- a. The cross section is rectangular.
- b. The reinforcement may be in any general pattern with no more than 20 rows of steel.
- c. The loading may consist of a uniaxial moment and an axial load. The axial load can be tension, compression, or zero.
- d. The ETL criteria on stress and strain are used to compute moment and load capacities.
- e. Reinforcement, in investigation or design, is assumed to be capable of developing stresses up to F_y . The user's attention is directed to American Concrete Institute (ACI) requirements on the tie steel necessary for making compression bars effective in developing stress.
- f. The program does not check concrete sections for general compliance with the ACI Code, however.

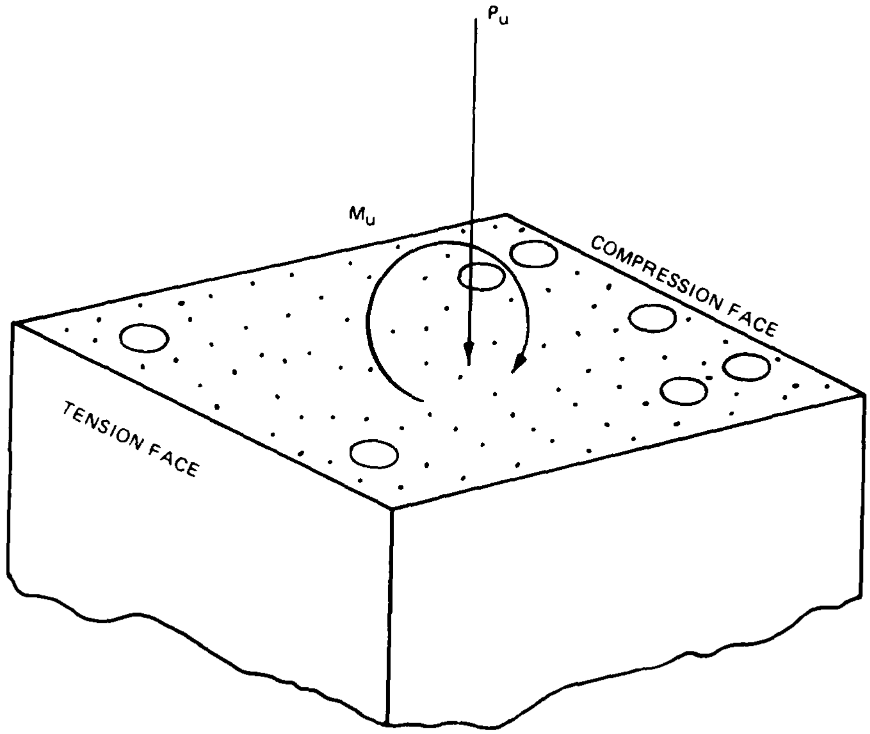


Figure 1. Applied load sign convention

Design Capability

3. Program CSTR will compute the area of steel required for a beam or for a column having a fixed width and depth. The program will not design the size of a member since, in most cases, selection of member sizes requires judgment. Procedures for describing steel patterns and computing the required area of steel are considerably different for beams when compared to columns. As a result, the input data for beam and column design must be prepared in a slightly different manner. Paragraphs 17 through 19 give more details on these differences.

Beams

4. In beams, bars are usually defined as rows of tension and compression steel with ductility also an important consideration. Therefore, for beam design the user is required to describe spacing criteria for tension steel,

spacing criteria for compression steel, and limits on steel ratios. CSTR checks the need for tension steel and adds what is required, beginning with the outermost layer, progressing inward (Figure 2). Likewise, the need for compression steel is examined and, if required, is added, progressing from outer to inner layers. A sufficient amount of compression steel is added to satisfy steel ratio limits on tension steel (0.25 P_b , for example).

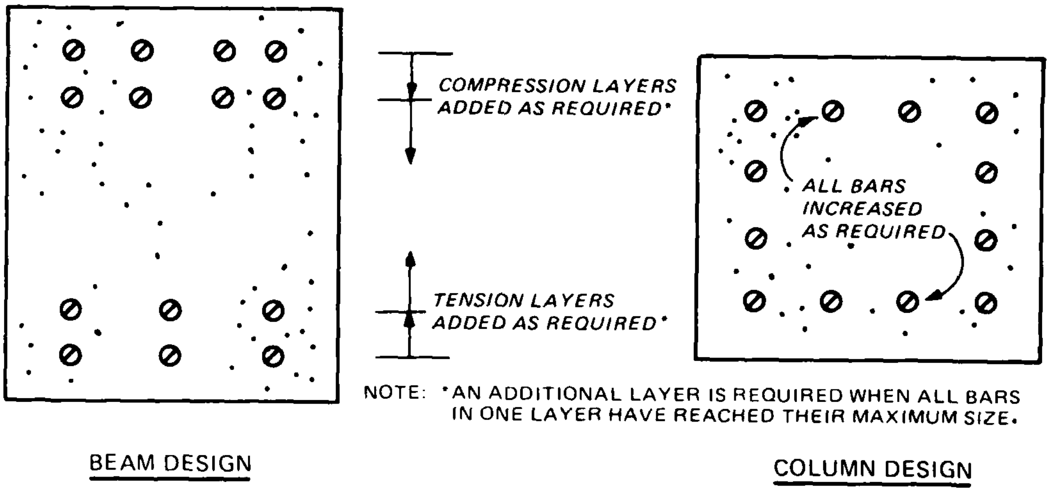


Figure 2. Reinforcement design procedure

Columns

5. In column design, bars are rarely described as being in tension or compression layers; rather, all bars are described in a set pattern. Also, since ductility is normally not a consideration in column design, the user is required to describe a desired bar pattern and the minimum acceptable bar size. The program then computes the size of bars with the described pattern necessary to carry the loads. Slenderness effects are not considered and bars are assumed to be tied in accordance with the ACI Code.

Investigation Capability

6. The program's capabilities extend beyond design into investigation checking procedures.

Beams and columns

7. The program makes no distinction between beams and columns with its investigation procedure. Height and width of a rectangular section, as well

as bar areas and locations, are defined by the user. The program then computes the section's strength and compares this calculated strength with applied loads. CSTR displays the strength of a section in the form of an interaction diagram; therefore, use of this program requires an understanding of the principles of interaction diagrams. A brief explanation of interaction diagrams and their use is provided in paragraphs 10 through 16.

Ductility check

8. Limits on steel ratios are normally thought of as a means to ensure ductile behavior and are discussed herein as checks on ductility. In fact steel ratio limits in Corps criteria ensure both ductility and crack control. When the program is used for investigation purposes the user must input a maximum allowable steel ratio. In most cases of beam design and in some cases of column design it is important to stay within this maximum limit; therefore, the program checks for satisfaction of ductility requirements in the described section. In some cases of column investigation the user may choose to ignore the program's check on ductility, also maximum steel ratios set by the ACI for columns are not checked.

Theoretical Background

9. Making full use of program CSTR requires an understanding of interaction diagrams and how they are used.

Interaction diagrams

10. An interaction diagram is plotted on a graph with axial force as the vertical axis and moment as the horizontal axis. An interaction diagram, ordinarily, is a plot of the moments and axial loads which cause a concrete member to fail.

11. Figure 3 shows an axial load of value P_a acting together with a moment of value M_a and causing a member of specified size to fail. The diagram, then, represents a failure envelope since points falling inside the curve do not cause failure and those falling on or outside the curve do cause

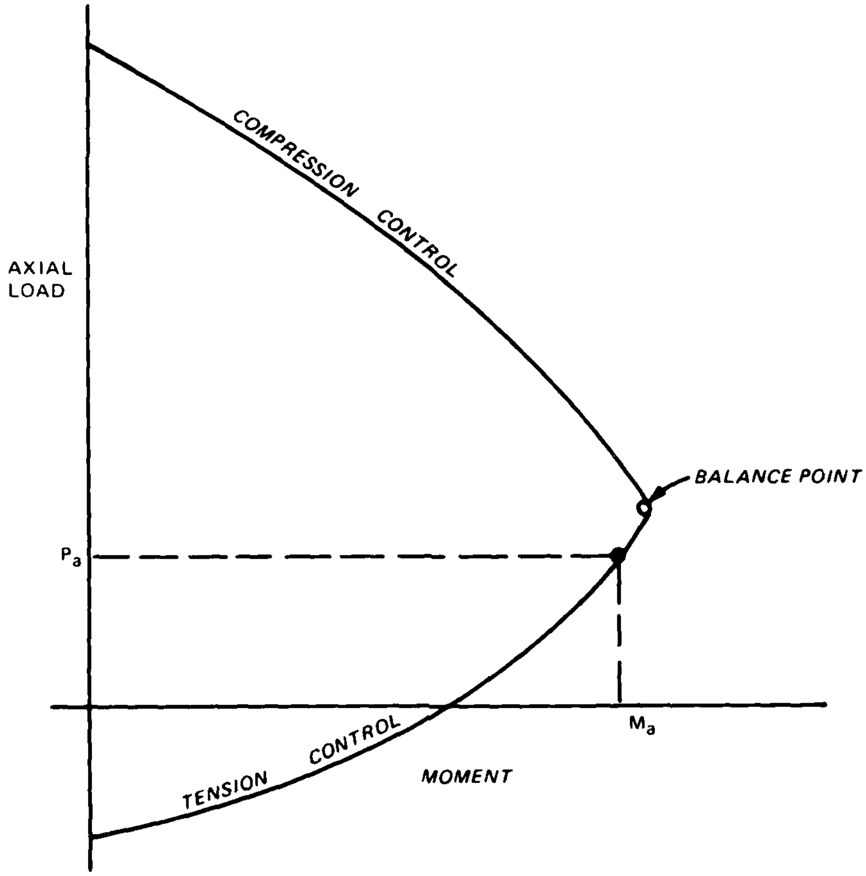


Figure 3. Interaction diagram

failure.* A reinforced concrete member is made of two differently behaving materials, steel and concrete, and the equations which define failure depend on whether the steel yields or the concrete crushes. The tension control range represents those axial loads and moments which cause the section to fail because the steel yields (Figure 3). Likewise, the compression control range represents those combinations of axial loads and moments which cause the member to fail by crushing of the concrete. The axial load and moment which cause simultaneous failure of steel and concrete is the balance point.

---

* The term failure is used in discussion; however, failure is actually defined by the ACI as occurring when concrete strains reach 0.003. The ETL-265's definition for failure, or more appropriately "usable strength," is defined by concrete strains of 0.0015.

Stress-strain assumptions

12. The stress-strain assumptions used by CSTR are in accordance with criteria contained in ETL-265 (Figure 4). Strains are zero at the neutral axis and vary linearly from the neutral axis to a maximum value of 0.0015 at the extreme fiber. The compressive stresses in the beam are approximated by a rectangular stress block $0.85\ f'_c$ in magnitude and $\beta_m C$ high.

Usable load and moment

13. A general expression can be written for the axial load and moment in terms of C, and the location of the neutral axis, by using the stress-strain diagrams in Figure 4. The expressions for P_i and M_i are found by setting

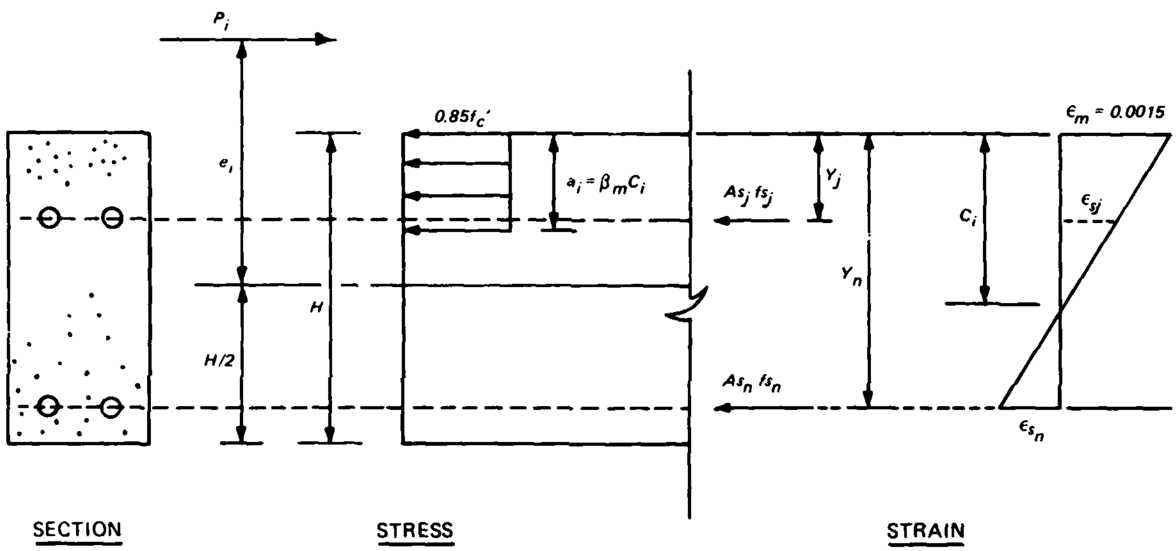


Figure 4. ETL-265 relationships for stress and strain

the sum of horizontal loads and moment equal to zero. Both conditions must be satisfied for equilibrium. Therefore, for any general value of C_i

$$P_i = 0.85f'_c\ \beta_m C_i b + \sum_{j=1}^{n} As_j\ fs_j$$

$$M_i = 0.85f'_c\ \beta_m C_i b \left(H - \frac{\beta_m C_i}{2.0}\right) - P_i \left(\frac{H}{2.0}\right) + \sum_{j=1}^{n} As_j\ fs_j\ (H - Y_j)$$

(n = number of layers of steel). An expression for the stress in each layer of steel in terms of C_i can be developed from the strain diagram

$$fs_j = (C_i \varepsilon_m - \varepsilon_m Y_j / C_i) E_s \qquad -f_y \le f_{sj} \le f_y$$

14. The general expressions for P_i and M_i shown above can generate an interaction diagram by iterating the value of C from near zero to near infinity and computing the values of P_i and M_i for each value of C_i. This, in effect, computes the full range of load and moment capacities of the section with all possible positions of the neutral axis.

Ductility

15. The ACI Code requires that for members with axial load less than $0.10f'_c bh$ the steel ratio cannot exceed $0.75f_b$. In comparison, the ETL-265 places more stringent restrictions on steel ratios. During the program's design process, if the tension steel required exceeds limitations on steel ratios, compression steel must be added. This addition of a sufficient amount of compression steel is made so that the portion of tension steel resisted by concrete compressive stresses does not exceed the specified upper limits on steel ratio (paragraph 10.3.3, ACI Code). For convenience, CSTR computes and prints the minimum size beam depth which can be used without compression steel. Columns are designed without regard for ductility.

Iterating to a solution

16. Paragraph 13 describes how an interaction diagram can be generated for a given problem. CSTR designs begin with a very small amount of steel and generates an interaction diagram. If the loading falls outside the envelope created by the diagram steel areas are increased and a new diagram is generated. This process continues until the diagram exceeds loadings and, in the case of beams, until steel ratio limits are satisfied.

Data File Preparation--Complete Description

17. The data file must be prepared in advance by using line numbers with three digits. One blank space must follow the line number; data values should be separated by one or more blanks. Lines may not be continued. Units are kips and inches, except that applied moments (RMU) are in kip-feet.

Appendix E contains a summary of the information in this paragraph.

Fixed data

18. The first four lines of the data file may be thought of as fixed data since these lines are used only once in a data file.

a. Job title. Two lines of job title must be first in the file. Each of the two lines must have a line number, a blank space, and up to 30 characters of job title.

b. Mode line.

LN MODE

where

LN = Line Number

MODE = 1 for investigation (paragraph 7)

2 for column design (paragraph 5)

3 for beam design (paragraph 4)

c. Properties line.

LN FC FY PEROB

where

LN = Line Number

FC = concrete ultimate strength f'_c , ksi

FY = steel yield strength f_y , ksi*

PEROB = limiting ratio of actual reinforcement to balance reinforcement. Use only when MODE = 1 (investigation) or 3 (beam design). It must be omitted when MODE = 2 . Usual values are 0.25 in ETL-265 except for conduits with large axial force where 0.375 is used.

Section data

19. Section data sets may be repeated without limit, in order to examine as many sections as desired.

a. Section title line. One line, with a line number, one blank space, then up to 30 characters of section and/or load case title.

b. Geometry line.

LN B H

where

LN = Line Number

* ETL-265 limits this to 48.0.

B = section width, in.

H = section total height, in.

c. Reinforcing lines. Refer to Figure 5 for reinforcement descriptions of investigation problems and column design; refer to Figure 6 for beam design.

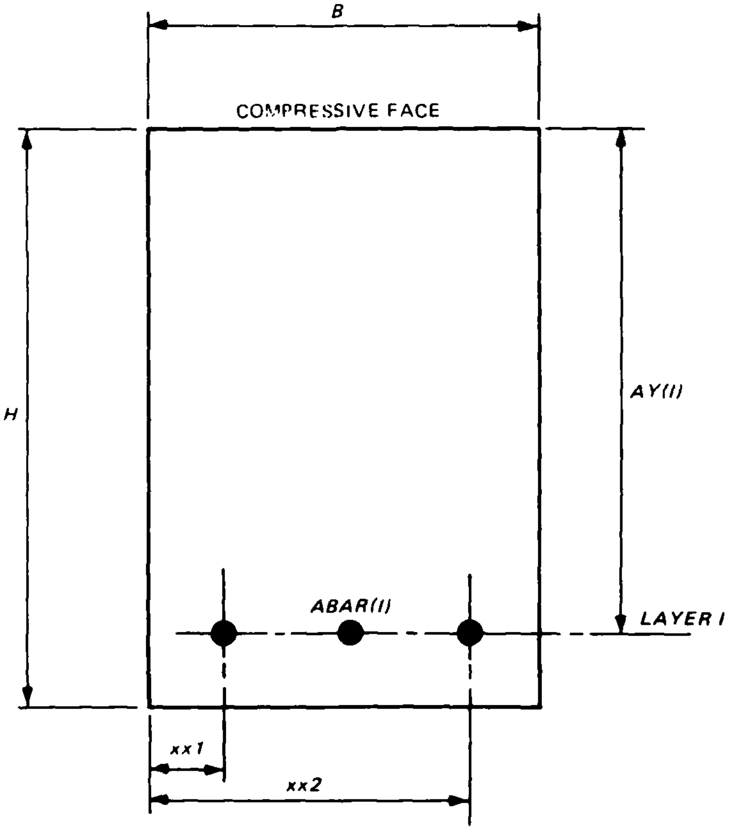


Figure 5. Investigation and column design variables

(1) If MODE = 1 for investigation or 2 for column design.

(a) LN NLAY

where

LN = Line Number

NLAY = number of layers of steel, may be zero

(b) (Use this line if NLAY is greater than zero, repeat the line NLAY times):

LN NBAR(I) ABAR(I) AY(I) XX1(I) XX2(I)

where

LN = Line Number

NBAR = number of bars in layer I

ABAR = area of one bar in layer I, in.^{2} for investigation. Minimum area of one bar in layer I for column design

AY = Y distance from compressive face to center of layer I, in.

XX1 = X distance from left side to center of left-most end bar of layer I, in.

XX2 = X distance from left side to center of right-most end bar in layer, in.

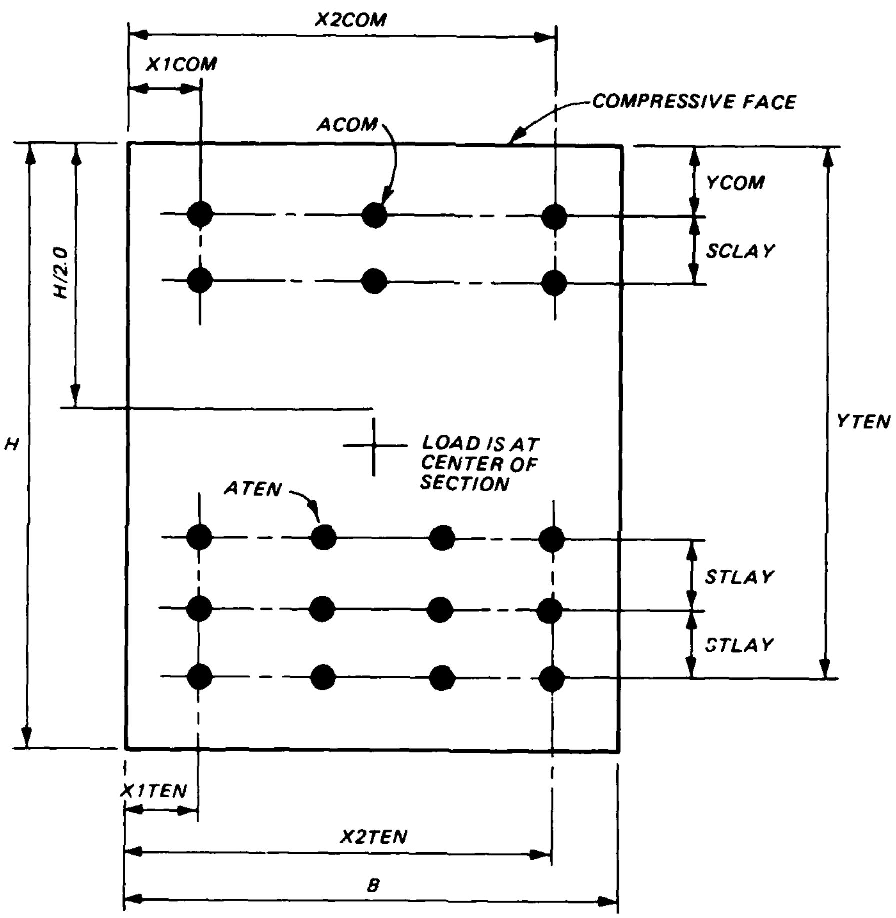


Figure 6. Beam design variables

(2) If MODE = 3 for beam design:

(a) LN NCOM ACOM YCOM X1COM X2COM SCLAY

where

LN = Line Number

NCOM = number of bars per compressive layer

ACOM = maximum area allowed for one bar in a compressive layer, in.^{2}

YCOM = Y distance from compressive face to the center of the outermost (top) layer, in.

X1COM = X distance from left side to the center of the left-most end bar in a layer of compressive steel, in.

X2COM = X distance from the left side to the center of the right-most end bar in a layer of compressive steel, in.

SCLAY = center-to-center spacing (Y-direction) between layers of compressive steel, in.

(b) LN NTEN ATEN YTEN X1TEN X2TEN STLAY

where

These tensile steel descriptions are similar to the corresponding descriptions for compressive steel in subparagraph (a) above.

d. Load line.

LN PU RMU

where

LN = Line Number

PU = factored axial load, kips, located at B/2 , H/2 , compression +

RMU = factored bending moment, kip-feet, including the moment induced by PU not actually located at H/2 . Always entered as a positive value, tending to cause compression in the face so considered when defining the reinforcing steel. Remember the code requirements for minimum moment when the theoretical moment is zero.

Running the Program

20. The following information is a step-by-step guide for preparing a data file and program operation.

a. Begin the program:

(1) Honeywell computers: (* prompt)

```
*FRN WESLIB/CORPS/X0066,R
```

(2) CDC computers: (/ prompt)

```
/OLD,CORPS/UN=CECELB
/BEGIN,,CORPS,X0066
```

(3) Harris computers: (no prompt)

```
*CORPS,X0066
```

b. Enter the data file name when requested.

c. When the bell sounds, the program will pause for the user to make any hard copies or notes of what is currently displayed, then press the "RETURN" key to continue.

d. The message "END OF DATA" indicates that all of the data have been processed without file read errors. Refer to paragraph 25 for an explanation of error messages.

Interpretation of Output

21. Output interpretation and investigation following a program is as vital to its success as the preliminaries for the actual run.

Investigation (MODE = 1)

22. The Figures 1 and 2 must be studied as the output is understood and applied.

a. Figure 1 includes tables of basic data and a picture of the section. The analysis parameters β_m , e_{max} , f_c/f'_c , ϕ_{axial} , and $\phi_{flexure}$ are listed.

b. Figure 2:

(1) Two P/M interaction curves, one with the capacity reduction factor PHI included ("DESIGN STRENGTH") and one without ("NOMINAL STRENGTH"). The nominal strength curve is annotated with the axial force strength upper limit value. The balance point is indicated with an * .

(2) PU, RMU, and the PHI factor used for the given loading.

(3) Pass/fail message relating to the ability of the section to resist the applied PU and RMU, with PHI included. The admissible range is assumed to be within the "DESIGN STRENGTH" curve, without regard for ductility requirement PEROB.

Column design (MODE = 2)

23. Column design is composed of two figures as described below.

a. Figure 1: Tables of basic data and picture of final section as designed. The bar areas in the table of "Reinforcement Areas and Positions" are as designed, not the minimum values in the data input. Analysis parameters used are listed.

b. Figure 2: Same as for investigation, plus the minimum effective depth required with the input value of B to yield an acceptable section without compressive reinforcement.

Beam design (MODE = 3)

24. Beam design, as in column design, is shown by figures made up of data tables as listed:

a. Figure 1: Tables of basic data and picture of final section as designed. The bar areas in the table of "Reinforcement Areas and Positions" are as designed and not the limiting values in the data file. Gross steel ratios for tensile and for compressive steel are listed.

b. Figure 2: Same as for Column Design except that a message on the right side of the figure shows compliance with ductility requirement PEROB.

Error Messages

25. Listed below are possible error messages and a brief explanation of each one:

a. The message "### DATA ERROR ### LAST LINE WAS nnn" means one of several things:

(1) Improper value for MODE, in which case nnn will be the line number of the MODE line in the data file.

(2) Incomplete data file, either one item or an entire line missing, in which case nnn will be the number of the last line in the file.

(3) A decimal point used with a data item whose name begins with the letters M or N , in which case nnn will be the number of the line containing the improper decimal point.

(4) A misplaced Job Name or Section Name line, in which case nnn will be the number of the misplaced Name line.

b. If MODE = 2 for column design, a message "A REINF. DESIGN CANNOT BE FOUND--COLUMN SIZE MUST BE INCREASED" means that the bar size found to be needed exceeded 100 in.^{2}*

c. If MODE = 3 for ductile beam design, a message "A REINF. DESIGN CANNOT BE FOUND--EITHER BEAM SIZE OR BAR SIZE MUST BE INCREASED" means that so many layers of reinforcing containing bars of the specified quantity and maximum size were needed that the tensile and compressive reinforcing patterns overlapped.

Special Uses of Program

26. The program is versatile in its uses and specific areas are described in the following paragraphs. Call the authors for information on advanced research capabilities.

---

* A table of factors for converting US customary (non-SI) units of measurement to metric (SI) units is presented on page 3.

Slab design

27. Slabs may be designed by inputting a 12.0-in.-wide strip.

Unreinforced section

28. An unreinforced section can be analyzed by inputting NLAY = 0 in the reinforcement data and omitting bar descriptions.

Nonductile beam design

29. If the user wants to design a beam, forcing the design to be single reinforced without regard for ductility, the column design procedure can be used. Reinforcement can be described as layers only in the tensile face.

Sample Problems

30. A sample investigation problem is presented in Appendix A, a sample column design problem is presented in Appendix B, and a sample beam problem is presented in Appendix C. Verification of a problem from a WES report is given in Appendix D and an abbreviated description of a data file preparation is included in Appendix E.

Appendix A: Sample Investigation Problem

Fixed data:

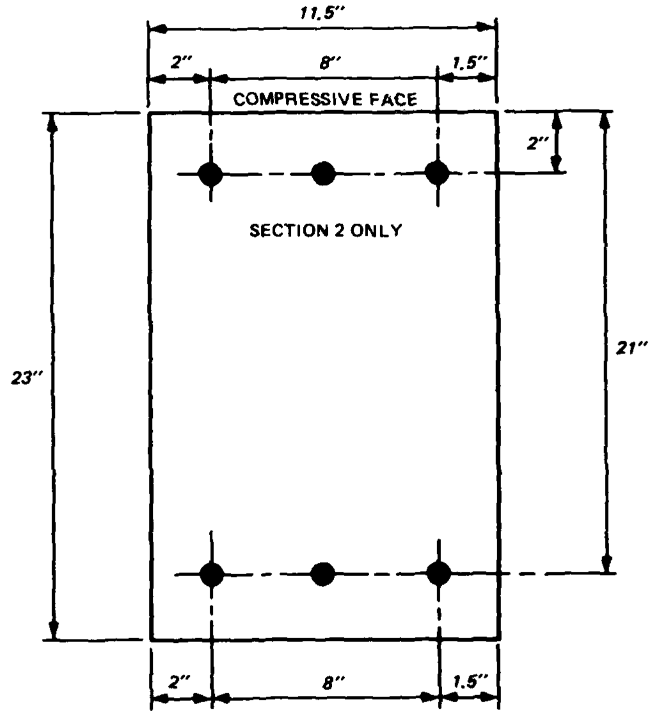
f'_c = 3.0 ksi, f_y = 40.0 ksi

Section 1:

3 bars @ 0.95 $\boxed{11}$/bar

P_u = 42 kip

M_u = 157 k-ft



Section 2 (Appendix C design):

top reinforcement

3 bars @ 0.37 $\boxed{11}$/bar

bottom reinforcement

3 bars @ 0.93 $\boxed{11}$/bar

P_u = 46.0 k

M_u = 170.0 k-ft

Contents:

Problem description

Computer run

```
*LIST INVD

100 PROGRAM X0066 DEMO
110 INVESTIGATION
200 1
210 3.0  40.0  0.375
300 11.5 X 23 WITH 1 LAYER
400 11.5  23.0
500 1
510 3  0.95  21.0  2.0  10.0
600 42.0  157.0
700 Appendix C problem
710 11.5  23.0
720 2
730 3  0.37   2.0  2.0  10.0
740 3  0.93  21.0  2.0  10.0
750 46.0  170.0


*FRN WESLIB/CORPS/X0066,R


        10/28/83    12.925

 THE BELL WILL RING AT EACH PAUSE FOR YOU TO COPY
 WHAT YOU WANT, THEN PRESS "RETURN" TO CONTINUE.


PROGRAM X0066 -- CSTR -- 713-F3-R0 066
CONCRETE STRENGTH INVESTIGATION & DESIGN
REV 0.1 -- SEPTEMBER 1983

ENTER NAME OF DATA FILE
*INVD
```

```
PROGRAM X0066 -- CSTR -- 713-F3-R0 066
CONCRETE STRENGTH INVESTIGATION & DESIGN

DIMENSIONS OF CONCRETE SECTION
------------------------------
WIDTH(B)          HEIGHT(H)
INCHES            INCHES
  11.500            23.000

REINFORCEMENT AREAS AND POSITIONS
---------------------------------
LAYER    NO.    AREA     Y       X1      X2
NO.      BARS   BAR    (IN.)   (IN.)   (IN.)
  1        3    0.95   21.00    2.00   10.00

MATERIAL CONSTANTS
------------------
F'C =  3.000 KSI
FY = 40.000  KSI

FACTOR p/p-bal, PEROB = 0.375

ANALYSIS FOLLOWS ETL 1110-2-265:
   STRESS BLOCK DEPTH RATIO, BM = 0.550
   MAXIMUM CONCRETE STRAIN, EMAX = 0.001500
   CONCRETE STRESS RATIO fc/f'c, FCR = 0.8500
   PHI FOR FLEXURE, PHIF = 0.900
   PHI FOR AXIAL LOAD, PHIA = 0.700
```

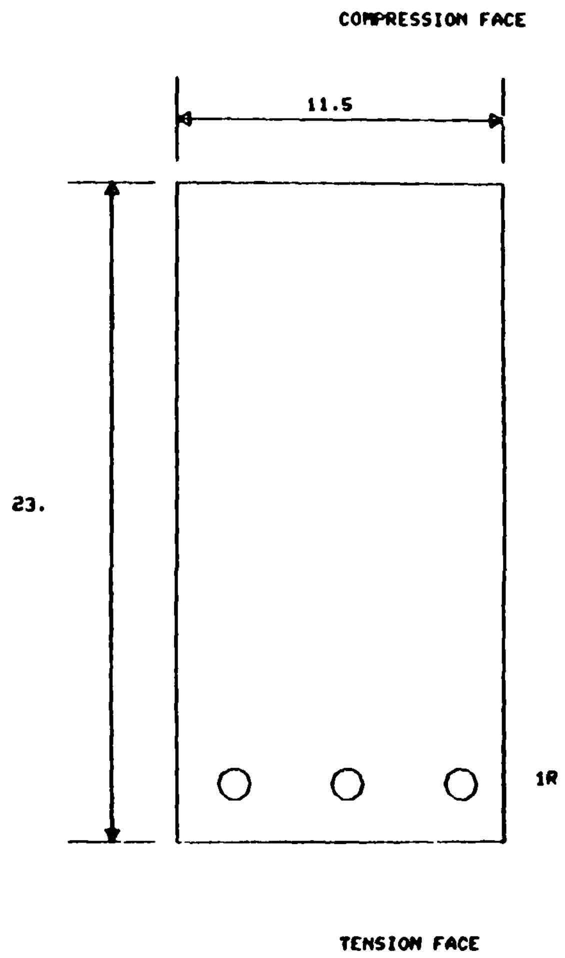


Figure 1. BASIC DATA SUMMARY

PROGRAM X0066 DEMO
INVESTIGATION
11.5 X 23 WITH 1 LAYER

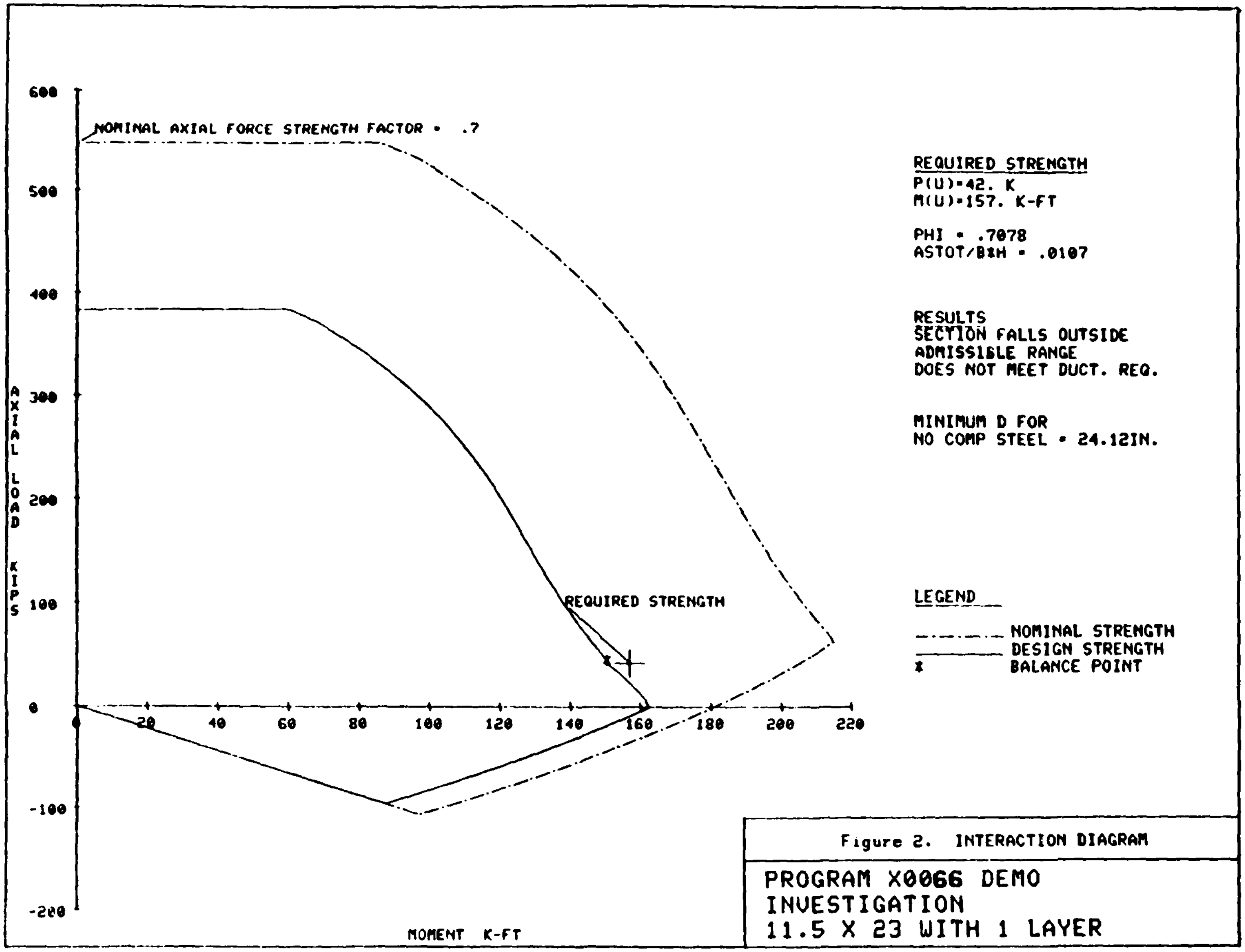


Figure 2. INTERACTION DIAGRAM

```
PROGRAM X0066 -- CSTR -- 713-F3-R0 066
CONCRETE STRENGTH INVESTIGATION & DESIGN

DIMENSIONS OF CONCRETE SECTION
------------------------------
WIDTH(B)          HEIGHT(H)
INCHES            INCHES
  11.500            23.000

REINFORCEMENT AREAS AND POSITIONS
---------------------------------
LAYER   NO.    AREA      Y        X1        X2
NO.     BARS   BAR     (IN.)     (IN.)     (IN.)
  1      3     0.37     2.00      2.00     10.00
  2      3     0.93    21.00      2.00     10.00

MATERIAL CONSTANTS
------------------
F'C = 3.000 KSI
FY = 40.000 KSI

FACTOR p/p-bal, PEROB = 0.375

ANALYSIS FOLLOWS ETL 1110-2-265:
   STRESS BLOCK DEPTH RATIO, BM = 0.550
   MAXIMUM CONCRETE STRAIN, EMAX = 0.001500
   CONCRETE STRESS RATIO fc/f'c, FCR = 0.8500
   PHI FOR FLEXURE, PHIF = 0.900
   PHI FOR AXIAL LOAD, PHIA = 0.700
```

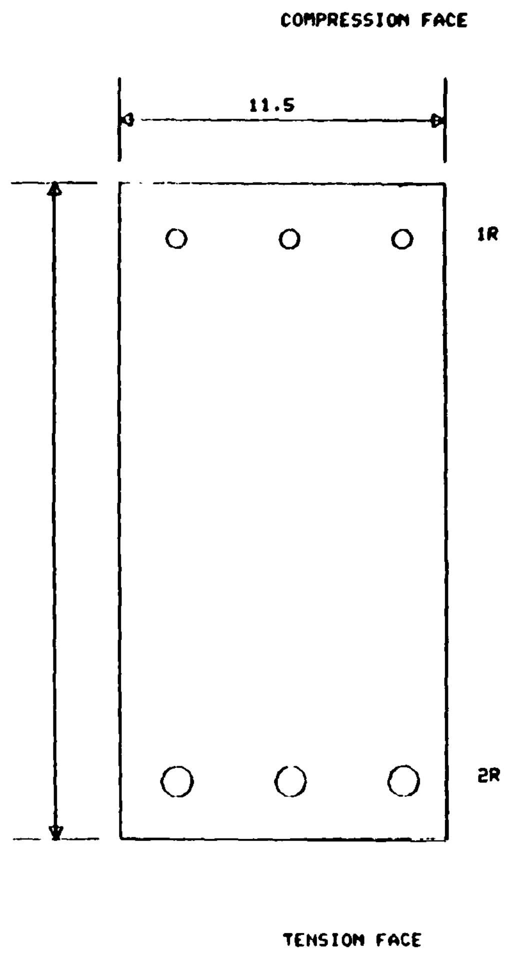
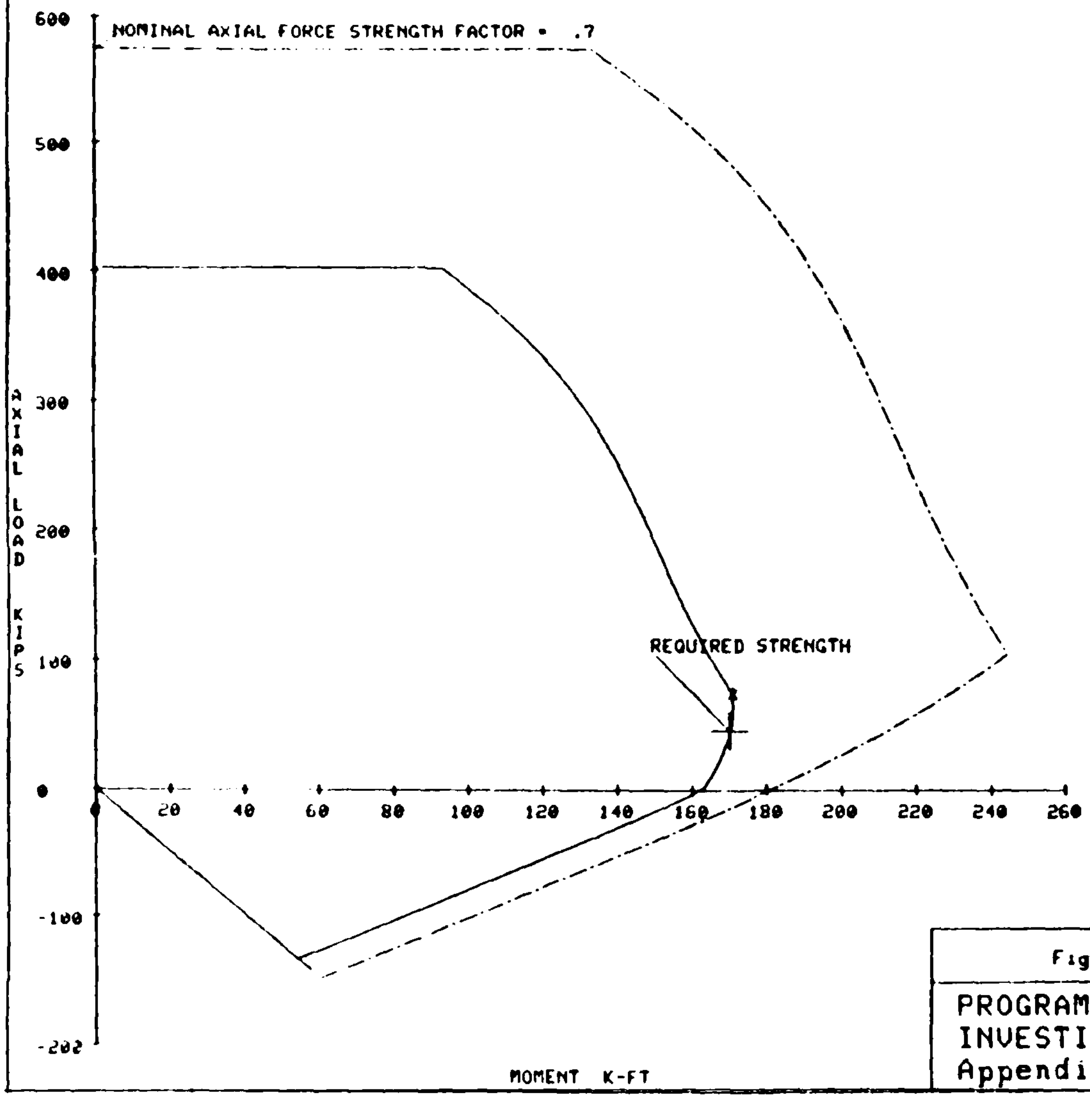


Figure 1. BASIC DATA SUMMARY

PROGRAM X0066 DEMO
DUCTILE BEAM DESIGN
11.5 X 23 W/COMP ALLOWED



REQUIRED STRENGTH
P(U)=46. K
M(U)=170. K-FT

PHI = .774
ASTOT/B*H = .0147

RESULTS
SECTION FALLS WITHIN
ADMISSIBLE RANGE
MEETS DUCTILITY REQ.

MINIMUM D FOR
NO COMP STEEL = 24.02IN.

LEGEND

— - — - NOMINAL STRENGTH
———— DESIGN STRENGTH
* BALANCE POINT

Figure 2. INTERACTION DIAGRAM

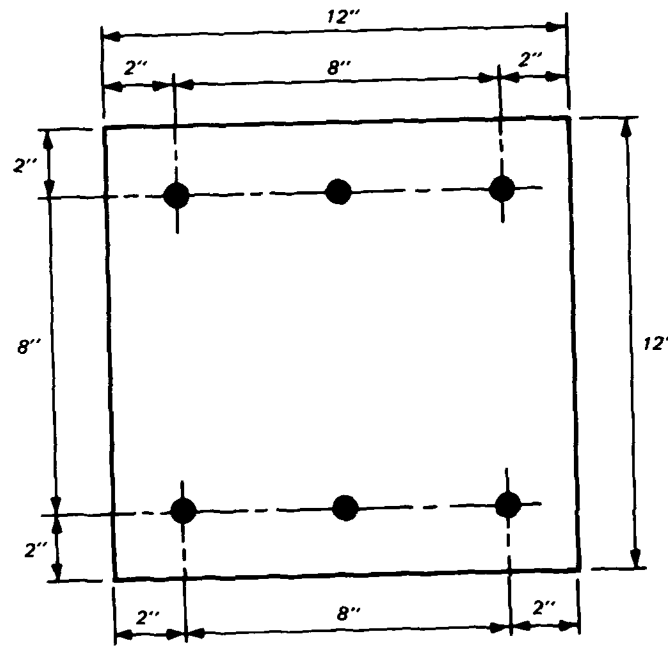
PROGRAM X0066 DEMO
INVESTIGATION
Appendix C problem

END OF DATA

*

Appendix B: Sample Column Design

$f'_c = 3.0$ ksi
$f_y = 40.0$ ksi
6 bars @ 0.1 $\boxed{''}$/bar, min.
$P_u = 50.0$ kips
$M_u = 50.0$ in.-kips



Contents:

Problem description

Computer run

```
*LIST COLD

100 PROGRAM X0066 DEMO
110 COLUMN DESIGN
200 2
210 3.0  40.0
300 12 X 12
400 12.0  12.0
500 2
510 3  0.1   2.0  2.0  10.0
520 3  0.1  10.0  2.0  10.0
600 50.0  50.0


*FRN WESLIB/CORPS/X0066,R


        10/14/83    15.235

 THE BELL WILL RING AT EACH PAUSE FOR YOU TO COPY
 WHAT YOU WANT, THEN PRESS "RETURN" TO CONTINUE.


PROGRAM X0066 -- CSIDE -- 713-F3-R0 066
CONCRETE STRENGTH INVESTIGATION & DESIGN
REV 0.1 -- SEPTEMBER 1983

ENTER NAME OF DATA FILE
=COLD
```

PROGRAM X0066 -- CSTR -- 713-F3-R0 066
CONCRETE STRENGTH INVESTIGATION & DESIGN

DIMENSIONS OF CONCRETE SECTION

WIDTH(B) INCHES	HEIGHT(H) INCHES
12.000	12.000

REINFORCEMENT AREAS AND POSITIONS

LAYER NO.	NO. BARS	AREA BAR	Y (IN.)	X1 (IN.)	X2 (IN.)
1	3	0.58	2.00	2.00	10.00
2	3	0.58	10.00	2.00	10.00

MATERIAL CONSTANTS

F'C = 3.000 KSI
FY = 40.000 KSI

ANALYSIS FOLLOWS ETL 1110-2-265:
STRESS BLOCK DEPTH RATIO, BM = 0.550
MAXIMUM CONCRETE STRAIN, EMAX = 0.001500
CONCRETE STRESS RATIO fc/f'c, FCR = 0.8500
PHI FOR FLEXURE, PHIF = 0.900
PHI FOR AXIAL LOAD, PHIA = 0.700

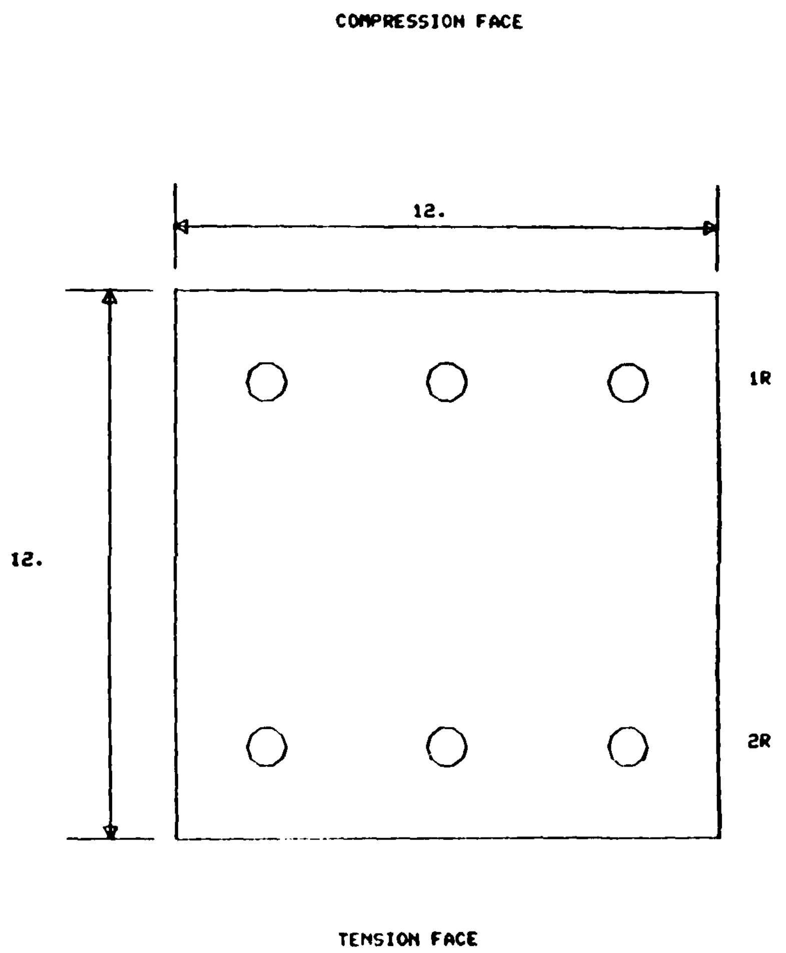


Figure 1. BASIC DATA SUMMARY

PROGRAM X0066 DEMO
COLUMN DESIGN
12 X 12

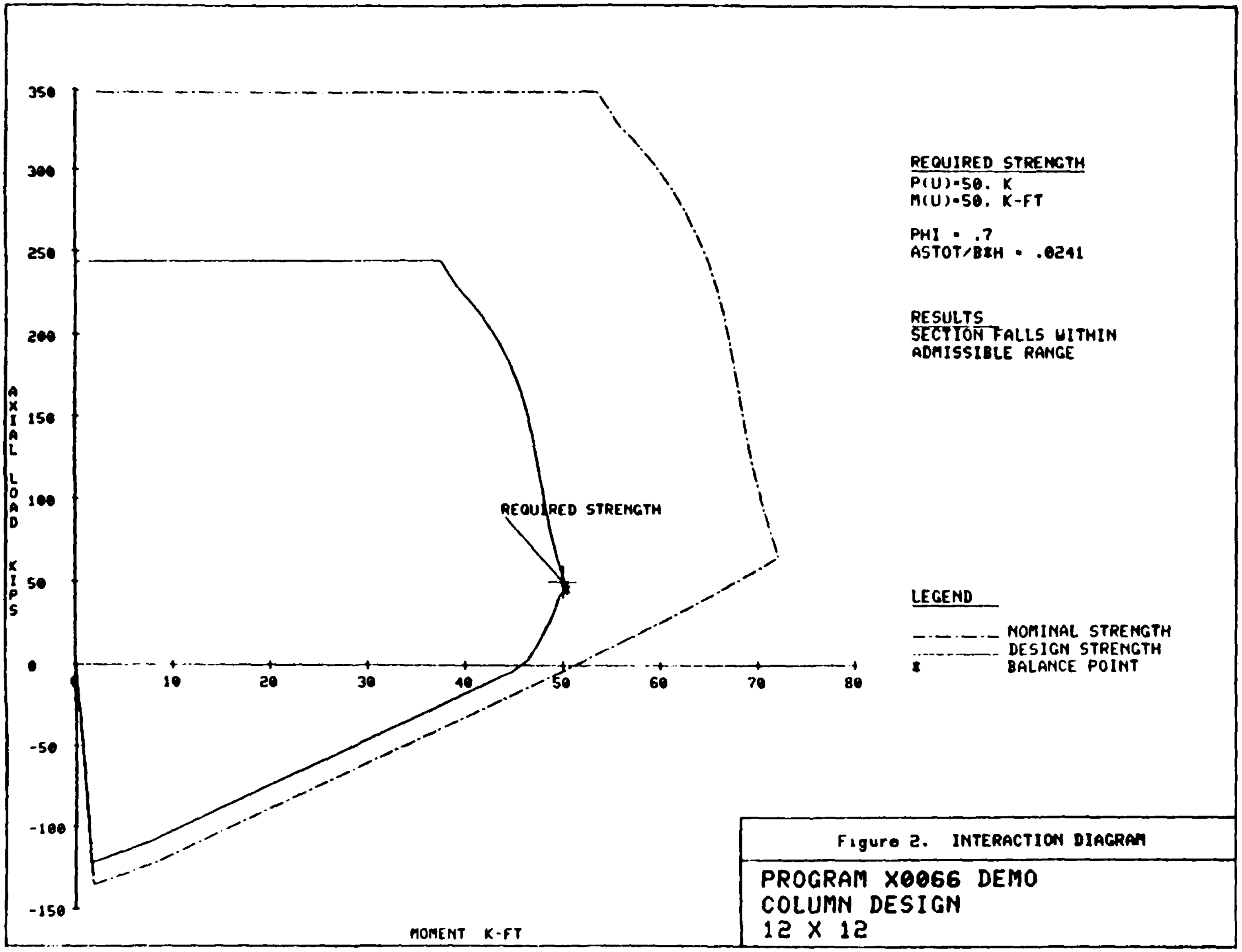


Figure 2. INTERACTION DIAGRAM

END OF DATA

*

Appendix C: Sample Ductile Beam Design

f'_c = 30.0 ksi

f_y = 40.0 ksi

$\dfrac{p}{p_{bal}}$ = 0.375 max

P_u = 46.0 K

M_u = 170.0 K-in load case 2

Compressive steel:

3 bars/layer

As_{max} = 5.0 $\boxed{''}$/bar

Tensile steel:

3 bars/layer

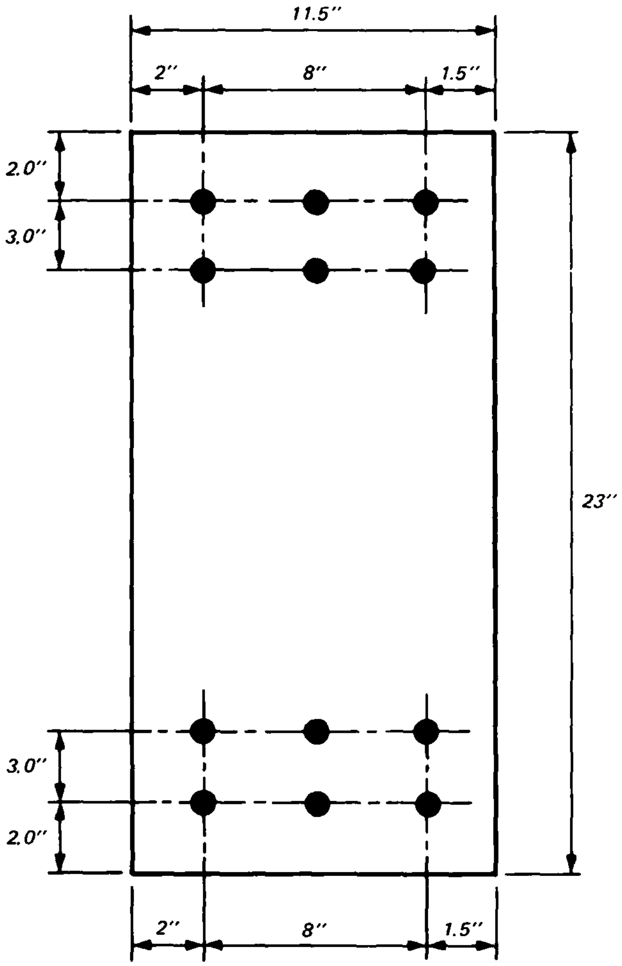
As_{max} = 5.0 $\boxed{''}$/bar

Contents:

Problem description

Computer run

Validation - See Appendix A



```
*LIST BEAMD

100 PROGRAM X0066 DEMO
110 DUCTILE BEAM DESIGN
200 3
210 3.0  40.0  0.375
300 11.5 X 23 W/COMP ALLOWED
400 11.5  23.0
500 3  5.0   2.0  2.0  10.0  3.0
510 3  5.0  21.0  2.0  10.0  3.0
600 46.0  170.0

*FRN WESLIB/CORPS/X0066,R


        10/14/83    15.267

 THE BELL WILL RING AT EACH PAUSE FOR YOU TO COPY
 WHAT YOU WANT, THEN PRESS 'RETURN' TO CONTINUE.



PROGRAM X0066 -- CSIDE -- 713-F3-R0 066
CONCRETE STRENGTH INVESTIGATION & DESIGN
REV 0.1 -- SEPTEMBER 1983


ENTER NAME OF DATA FILE
=BEAMD
```

PROGRAM X0066 -- CSTR -- 713-F3-R0 066
CONCRETE STRENGTH INVESTIGATION & DESIGN

DIMENSIONS OF CONCRETE SECTION

WIDTH(B) INCHES	HEIGHT(H) INCHES
11.500	23.000

REINFORCEMENT AREAS AND POSITIONS

LAYER NO.	NO. BARS	AREA BAR	Y (IN.)	X1 (IN.)	X2 (IN.)
1	3	0.37	2.00	2.00	10.00
2	3	0.93	21.00	2.00	10.00

MATERIAL CONSTANTS

F'C = 3.000 KSI
FY = 40.000 KSI

FACTOR p/p-bal, PEROB = 0.375

ANALYSIS FOLLOWS ETL 1110-2-265:
STRESS BLOCK DEPTH RATIO, BM = 0.550
MAXIMUM CONCRETE STRAIN, EMAX = 0.001500
CONCRETE STRESS RATIO fc/f'c, FCR = 0.8500
PHI FOR FLEXURE, PHIF = 0.900
PHI FOR AXIAL LOAD, PHIA = 0.700

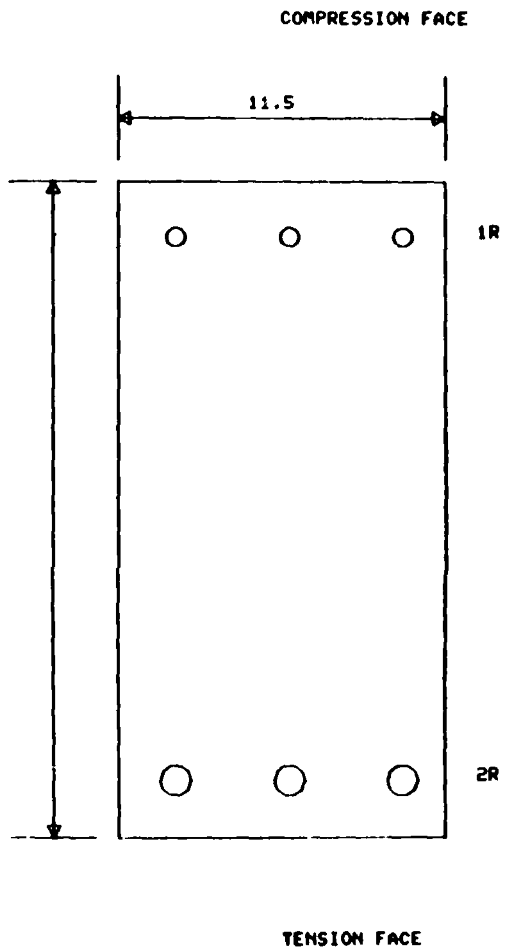


Figure 1. BASIC DATA SUMMARY

PROGRAM X0066 DEMO
INVESTIGATION
Appendix C problem

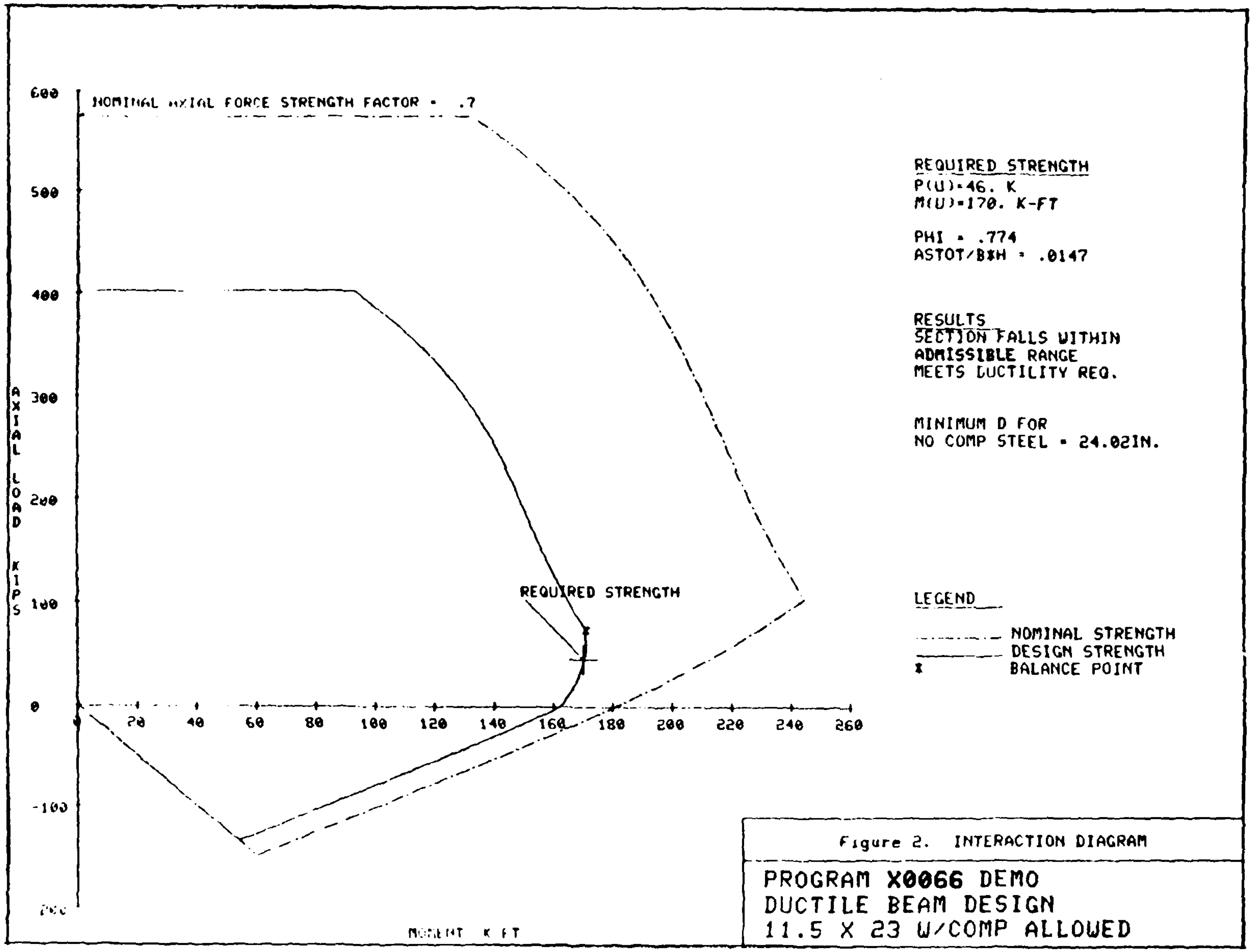


Figure 2. INTERACTION DIAGRAM

END OF DATA

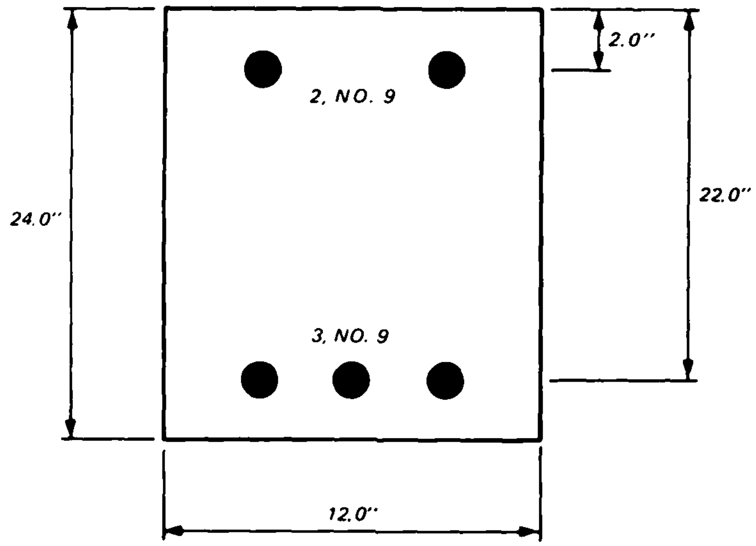
*

Appendix D: Verification

Contents

A. Investigation Problem:

A.1. Description of problem



NOTE: EQUATION REFERENCES ARE TO ETL. 1110-2-265

Concrete cross section

Note: equation references are to ETL-265

A.1.1. Singly Reinforced (Neglect 2, #9)

(1) Check $\phi P_{n(max)}$ eq. 3-2

(2) Check a tension control pt. eq. 3-5, eq. 3-6

(3) Check a compression control pt. eq. 3-8, eq. 3-9

A.1.2. Doubly Reinforced (Include 2, #9)

(1) Check $\phi P_{n(max)}$ eq. 3-12

(2) Check a tension control pt. eq. 3-14, eq. 3-15

(3) Check a compression control pt. eq. 3-18, eq. 3-19

A.1.3. Tension Member (Include 2, #9)

(1) Check $\phi P_{n(max)}$ eq. 3-23

(2) Check a tension control pt. eq. 3-24, eq. 3-25

A.2. Computations, computer runs:

Singly Reinforced

(ETL-265)

(1) $\phi P_{n(max)} = 0.7\phi[0.85f'_c(A_g - \rho bd) + F_y \rho bd]$ (3-2)

$= 0.7(0.7)[0.85(3)(12 \times 24) - 3) + 48(3)]$

$= 426.7^k$

(2) Compression control point

Assume e = 5.45"

$$e' = e + d - \frac{h}{2} \qquad (3\text{-}1)$$

$$= 5.45 + 22 - \frac{24}{2}$$

$$= 15.45''$$

$$k_u^3 + 2\left(\frac{e'}{d} - 1\right)k_u^2 + \left(\frac{E_s \varepsilon_m \rho e'}{0.425 f'_c d}\right)k_u - \frac{\beta_m E_s \varepsilon_m \rho e'}{0.425 f'_c d} = 0 \qquad (3\text{-}11)$$

$$k_u^3 + 2\left(\frac{15.45}{22} - 1\right)k_u^2 + \left[\frac{29{,}000(0.0015)(0.0114)(15.45)}{0.425(3)(22)}\right]k_u$$

$$- \frac{0.55(29{,}000)(0.0015)(0.0114)(15.45)}{0.425(3)(22)} = 0$$

$$k_u^3 - 0.595k_u^2 + 0.273k_u - 0.15 = 0$$

T + E

k_u	x
0.3	-0.095
0.5	-0.037
0.6	0.016
0.575	0.0004

$k_u = 0.575$

$$f_{su} = \frac{E_s \varepsilon_m (\beta_m - k_u)}{k_u} \geq -f_y \tag{3-10}$$

$$= \frac{29{,}000(0.0015)(0.55 - 0.575)}{0.575} \geq -48$$

$$= -1.89 > -48$$

$$\phi P_n = \phi(0.85 f'_c k_u - \rho f_{su}) bd \tag{3-8}$$

$$= 0.7[0.85(3)(0.575) - 0.0114(-1.89)]12(22)$$

$$= 274.9^k$$

$$\phi M_n = \phi(0.85 f'_c k_u - \rho f_{su}) \left[\frac{e'}{d} - \left(1 - \frac{h}{2d}\right)\right] bd^2 \tag{3-9}$$

$$= 0.7[0.85(3)(0.575) - 0.0114(-1.89)] \left[\frac{15.45}{22} - \left(1 - \frac{24}{44}\right)\right] 12(22)^2$$

$$= 0.7(1.49)(0.248)(5808)$$

$$= 125.2 \text{ k} - \text{F}$$

(3) Balanced point

$$k_m = \frac{\beta_m E_s \varepsilon_m}{E_s \varepsilon_m + f_y} \tag{3-4}$$

$$k_m = \frac{0.55(29{,}000)(0.0015)}{(20{,}000)(0.0015) + 48}$$

$$= 0.261$$

$$\frac{e'_m}{d} = \frac{2k_m - k_m^2}{2k_m - \dfrac{\rho f_y}{0.425f'_c}} \tag{3-3}$$

$$= \frac{2(0.261) - (0.261)^2}{2(0.261) - \dfrac{0.0114(48)}{0.425(3)}}$$

$$= \frac{0.4539}{0.0928}$$

$$= 4.89$$

$$\phi P_n = \phi(0.85f'_c k_u - \rho f_y)bd \tag{3-5}$$

$$= 0.7[0.85(3)(0.261) - 0.0114(48)]12(22)$$

$$= 21.9^k$$

$$\phi M_n = \phi\left[0.85f'_c k_u - \rho f_y\right]\left[\frac{e'}{d} - \left(1 - \frac{h}{2d}\right)\right]bd^2 \tag{3-6}$$

$$= 0.7[0.85(3)(0.261) - 0.0014(48)]\left[4.89 - \left(1 - \frac{24}{44}\right)\right]12(22)^2$$

$$= 0.7(0.1184)(4.435)(5808)$$

$$= 177.9 \text{ k - F}$$

(4) Pure flexure

$$\alpha = \frac{A_s A_y}{0.85f'_c b} \quad \text{(ACI 318-77)}$$

$$= \frac{3(48)}{0.85(3)(12)}$$

$$= 4.71$$

$$\phi M_n = \phi\left[A_s f_y\left(d - \frac{\alpha}{2}\right)\right]$$

$$= 0.9\left[3(48)\left(22 - \frac{4.71}{2}\right)\right]$$

$$= 212.2 \text{ k - F}$$

```
*L
010 PROGRAM VERIFICATION
020 INVESTIGATION
030 1
040 3 48 .25
050 SINGLY REINFORCED
060 12 24
070 1
080 3 1 22 3.5 8.5
090 0.0 0.0
*
```

PROGRAM X0008 -- CSTR -- 713-F3-R0 008
CONCRETE STRENGTH INVESTIGATION & DESIGN

DIMENSIONS OF CONCRETE SECTION

WIDTH(B) INCHES	HEIGHT(H) INCHES
12.000	24.000

REINFORCEMENT AREAS AND POSITIONS

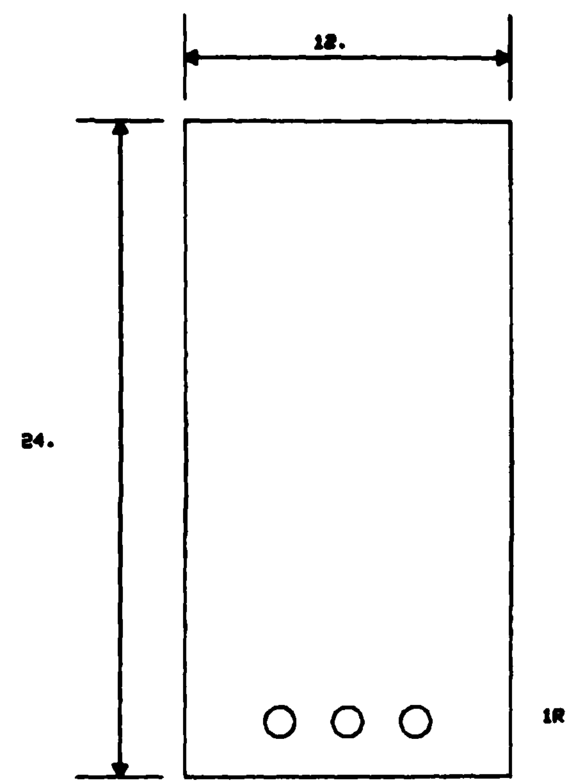
LAYER NO.	NO. BARS	AREA BAR	Y (IN.)	X1 (IN.)	X2 (IN.)
1	3	1.00	22.00	3.50	8.50

MATERIAL CONSTANTS

F'C = 3.000 KSI
FY = 48.000 KSI

ANALYSIS FOLLOWS ETL 1110-2-265:
STRESS BLOCK DEPTH RATIO, BM = 0.550
MAXIMUM CONCRETE STRAIN, EMAX = 0.001500
CONCRETE STRESS RATIO fc/f'c, FCR = 0.8500
PHI FOR FLEXURE, PHIF = 0.900
PHI FOR AXIAL LOAD, PHIA = 0.700

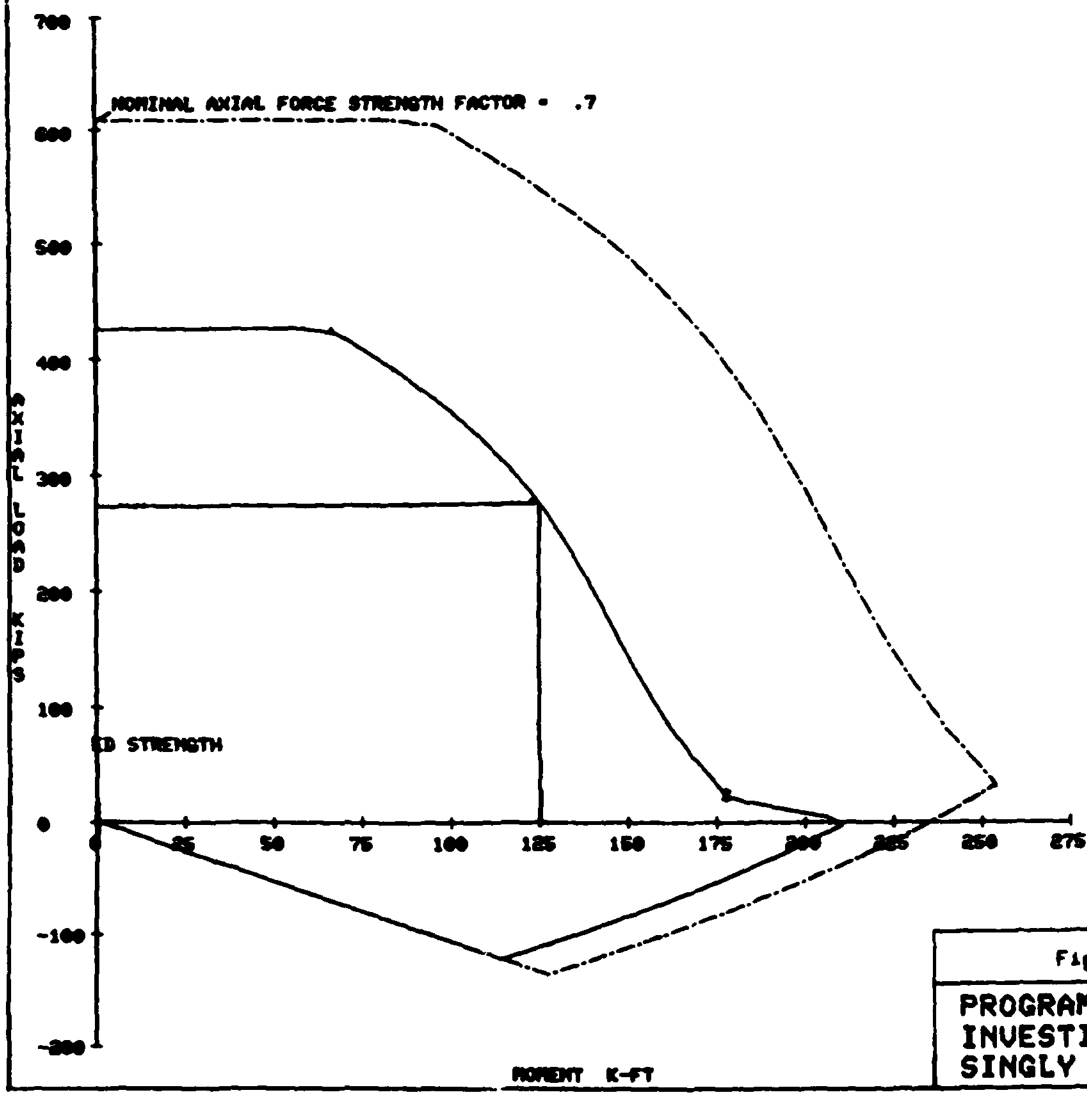
COMPRESSION FACE



TENSION FACE

Figure 1. BASIC DATA SUMMARY

PROGRAM VERIFICATION
INVESTIGATION
SINGLY REINFORCED



REQUIRED STRENGTH
P(U)=0. K
M(U)=0. K-FT

PHI = .9
ASTOT/B*H = .0104

RESULTS
SECTION FALLS WITHIN
ADMISSIBLE RANGE

MINIMUM D FOR
NO COMP STEEL = 0.IN.

LEGEND
-.-.-.-.- NOMINAL STRENGTH
———— DESIGN STRENGTH
* BALANCE POINT

Figure 2. INTERACTION DIAGRAM

PROGRAM VERIFICATION
INVESTIGATION
SINGLY REINFORCED

A.3. Computations, computer runs:

Doubly Reinforced

(1) $$\phi P_{n(max)} = 0.7\phi\{0.85f'_c[A_g - (\rho + \rho')bd] + f_y(\rho + \rho')bd\} \qquad (3\text{-}12)$$

$$= 0.7(0.7)\{0.85(3)[(12 \times 24) - (0.0114$$

$$+ 0.0076)12(22)] + 48(0.0114 + 0.0076)12(22)\}$$

$$= 0.49(721.6 + 240.8)$$

$$= 471.6^k$$

(2) Compression control point

assume e = 6.5"

$$e' = e + d - \frac{h}{2}$$

$$= 6.5 + 22 - \frac{24}{2}$$

$$= 16.5''$$

$$k_u^3 + 2\left(\frac{e'}{d} - 1\right)k_u^2 + \frac{E_s\varepsilon_m}{0.425f'_c}\left[(\rho + \rho)\left(\frac{e'}{d}\right) - \rho'\left(1 - \frac{d'}{d}\right)\right]k_u$$

$$- \frac{\beta_m E_s \varepsilon_m}{0.425f'_c}\left[\rho'\left(\frac{d'}{d}\right)\left(\frac{e'}{d} + \frac{d'}{d} - 1\right) + \rho\left(\frac{e'}{d}\right)\right] = 0 \qquad (3\text{-}22)$$

$$k_u^3 + 2\left(\frac{16.5}{22} - 1\right)k_u^2 + \frac{29,000(0.0015)}{0.425(3)}\left[(0.0114 + 0.0076)\left(\frac{16.5}{22}\right)\right.$$

$$\left. - 0.0076\left(1 - \frac{2}{22}\right)\right]k_u - \frac{0.55(29,000)(0.0015)}{0.425(3)}\left[0.0076\left(\frac{2}{22}\right)\left(\frac{16.5}{22} + \right.\right.$$

$$\left.\left. + \frac{2}{22} - 1\right) + 0.0114\left(\frac{16.5}{22}\right)\right] = 0$$

$$k_u^3 - 0.5k_u^2 + 0.25k_u - 0.1584 = 0$$

$T + \sigma$

k_u	x
0.3	-0.101
0.5	-0.033
0.6	-0.028
0.55	-0.006
0.56	0.0004

$$f_{su} = \frac{E_s \varepsilon_m (\beta_m - k_u)}{k_u} \geq -f_y \qquad (3\text{-}20)$$

$$= \frac{29{,}000(0.0015)(0.55 - 0.56)}{0.56} \geq -48$$

$$= -0.78 \geq -48$$

$$f'_{su} = \frac{E_s \varepsilon_m \left[k_u - \beta_m\left(\frac{d'}{d}\right)\right]}{k_u} \leq f_y \qquad (3\text{-}21)$$

$$= \frac{29{,}000(0.0015)\left[0.56 - 0.55\left(\frac{2}{22}\right)\right]}{0.56}$$

$$= 39.62 < 48$$

$$\phi M_n = \phi\left[0.85 f'_c k_u + \rho' f'_{su} - \rho f_{su}\right]\left[\frac{e'}{d} - \left(1 - \frac{h}{2d}\right)\right] bd^2 \qquad (3\text{-}19)$$

$$= 0.7[0.85(3)(0.56) + (0.0076)(39.62)$$

$$- (0.0114)(-0.78)]\left[\frac{16.5}{22} - \left(1 - \frac{24}{44}\right)\right]12(22)^2$$

$$= 0.7(1.738)(0.295)5808$$

$$= 173.7 \text{ k - F}$$

$$\phi P_n = \phi(0.85 f'_c k_u + \rho' f'_{su} - \rho f_{su})bd$$

$$= 0.7[0.85(3)(0.56) + 0.0076(39.62) - 0.0114(-0.78)]12(22)$$

$$= 321.2^k$$

(3) Balanced point

$$k_m = 0.261 \quad \text{(from Part A)} \tag{3-11}$$

$$f'_{su} = \frac{\left(k_u - \beta_m \frac{d'}{d}\right)}{(\beta_m - k_u)} E_s \epsilon_y \leq f_y \tag{3-16}$$

$$= \frac{\left[0.261 - 0.55\left(\frac{2}{22}\right)\right]}{(0.55 - 0.261)} 48 \leq 48$$

$$= 35.0 \leq 48$$

$$\frac{e'_m}{d} = \frac{2k_m - k_m^2 + \dfrac{\rho' f'_{su}\left(1 - \frac{d'}{d}\right)}{0.425 f'_c}}{2k_m - \dfrac{\rho f_y}{0.425 f'_c} + \dfrac{\rho' f'_{su}}{0.425 f'_c}} \tag{3-13}$$

$$= \frac{2(0.261) - (0.261)^2 + \dfrac{0.0076(35)\left(1 - \frac{2}{22}\right)}{0.425(3)}}{2(0.261) - \dfrac{0.0114(48)}{0.425(3)} + \dfrac{0.0076(35)}{0.425(3)}}$$

$$= \frac{0.644}{0.301}$$

$$= 2.14$$

$$\phi P_n = \phi\left[0.85 f'_c k_m + \rho' f'_{su} - \rho f_y\right] bd \tag{3-14}$$

$$= 0.7[0.85(3)(0.261) + 0.0076(35) - 0.0114(48)]12(22)$$

$$= 71.0^k$$

$$\phi M_n = \phi\left[0.85f'_c k_m + \rho' f'_{su} - \rho f_y\right]\left[\frac{e'_m}{d} - \left(1 - \frac{h}{2d}\right)\right]bd^2 \qquad (3\text{-}15)$$

$$= 0.7[0.85(3)(0.261) + 0.0076(35) - 0.0114(48)]\left[2.14 - \left(1 - \frac{24}{44}\right)\right]12(22)^2$$

$$= 0.7(0.384)(1.685)5808$$

$$= 219.3 \text{ k - F}$$

(4) Pure flexure

$$a = \frac{(A_s - A'_s)f_y}{0.85f'_c b} \qquad \text{(ACI 318-77)}$$

$$= \frac{(3 - 2)48}{0.85(3)(12)}$$

$$= 1.57$$

$$\phi M_m = \phi\left[(A_s - A'_s)f_y\left(d - \frac{a}{2}\right) + A'_s f_y (d - d')\right]$$

$$= 0.9\left[(3 - 2)48\left(22 - \frac{1.57}{2}\right) + 2(48)(22 - 2)\right]$$

$$= 0.9(1018.32 + 1920.0)$$

$$= 220.4 \text{ k - F}$$

```
010 PROGRAM VERIFICATION
020 INVESTIGATION
030 1
040 3 48 .25
050 DOUBLY REINFORCED
060 12 24
070 2
080 3 1 22 3.5 8.5
085 2 1 2 4 8
090 0.0 0.0
*
```

PROGRAM X0086 -- CSTR -- 713-F3-R0 006
CONCRETE STRENGTH INVESTIGATION & DESIGN

DIMENSIONS OF CONCRETE SECTION

WIDTH(B) INCHES	HEIGHT(H) INCHES
12.000	24.000

REINFORCEMENT AREAS AND POSITIONS

LAYER NO.	NO. BARS	AREA BAR	Y (IN.)	X1 (IN.)	X2 (IN.)
1	3	1.00	22.00	3.50	8.50
2	2	1.00	2.00	4.00	8.00

MATERIAL CONSTANTS

F'C = 3.000 KSI
FY = 48.000 KSI

ANALYSIS FOLLOWS ETL 1110-2-265:
STRESS BLOCK DEPTH RATIO, BM = 0.550
MAXIMUM CONCRETE STRAIN, EMAX = 0.001500
CONCRETE STRESS RATIO fc/f'c, FCR = 0.8500
PHI FOR FLEXURE, PHIF = 0.900
PHI FOR AXIAL LOAD, PHIA = 0.700

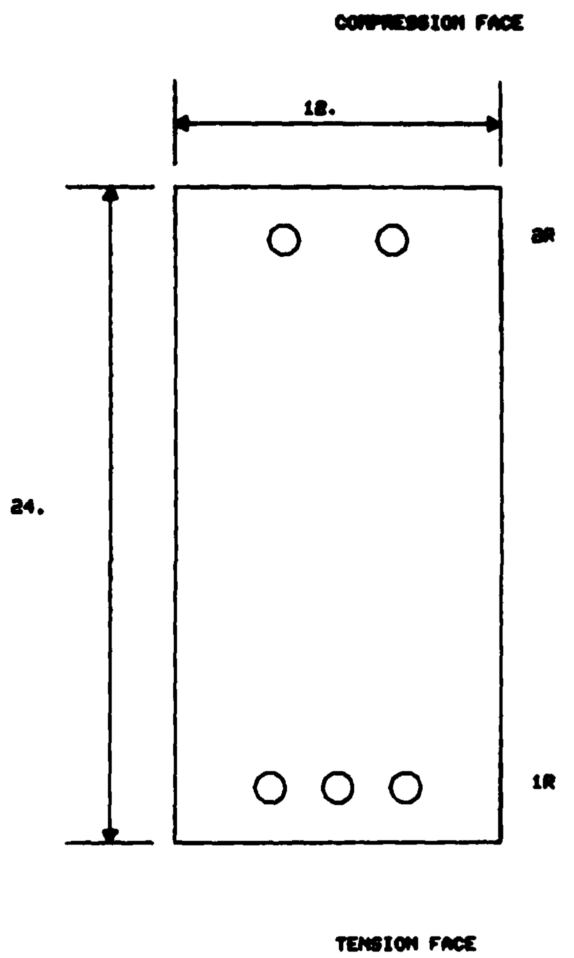
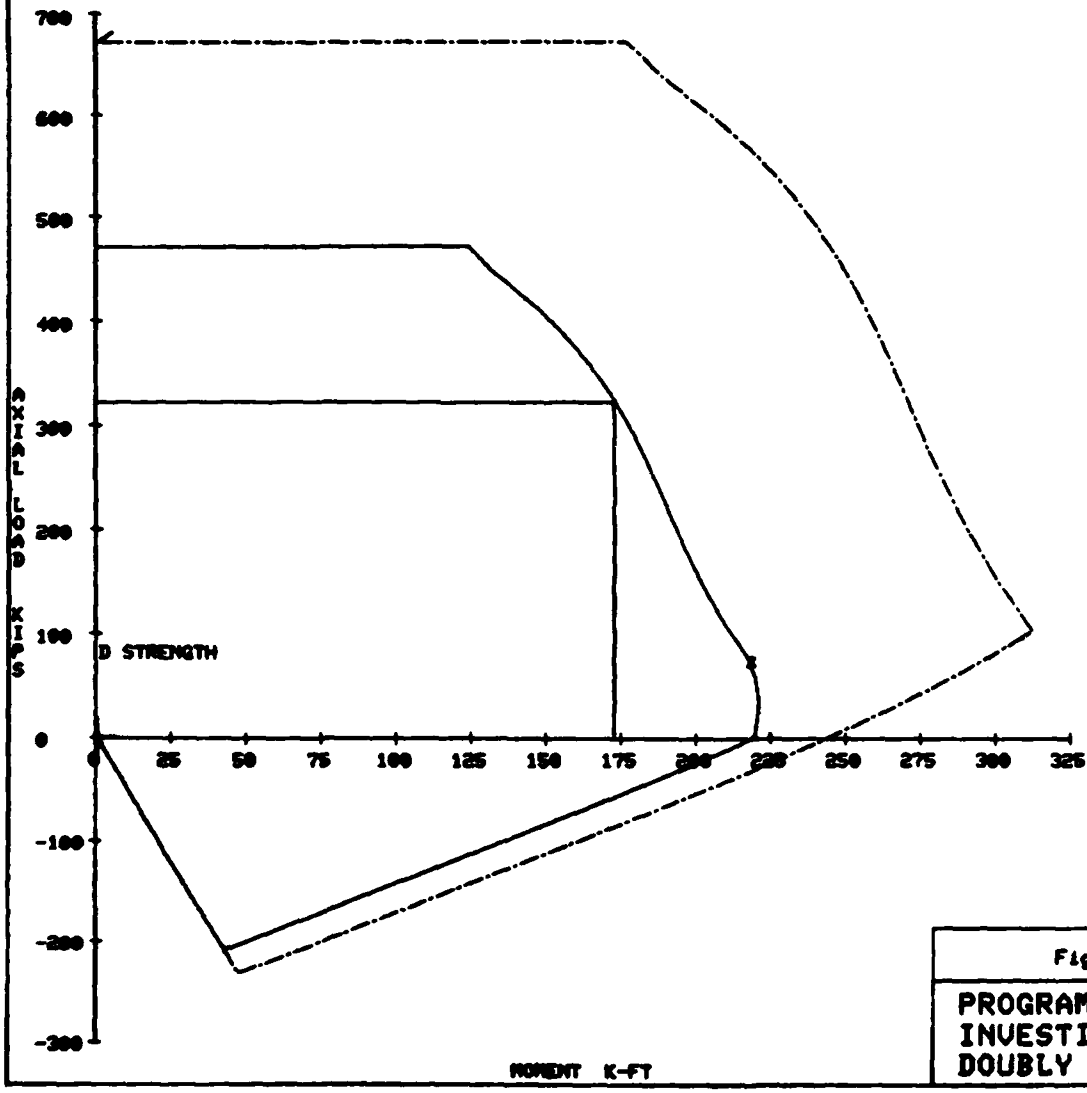


Figure 1. BASIC DATA SUMMARY

PROGRAM VERIFICATION
INVESTIGATION
DOUBLY REINFORCED



REQUIRED STRENGTH
P(U)=0. K
M(U)=0. K-FT

PHI = .9
ASTOT/B*H = .0173

RESULTS
SECTION FALLS WITHIN
ADMISSIBLE RANGE

MINIMUM D FOR
NO COMP STEEL = 0.IN.

LEGEND
—·—·— NOMINAL STRENGTH
——— DESIGN STRENGTH
x BALANCE POINT

Figure 2. INTERACTION DIAGRAM

PROGRAM VERIFICATION
INVESTIGATION
DOUBLY REINFORCED

A.4. Computations, computer runs:

Tension Member

(1) $$\phi P_{n(max)} = 0.8\phi(\rho + \rho')f_y bd \qquad (3\text{-}23)$$

$$= 0.8(0.9)(0.0114 + 0.0076)48(12)(22)$$

$$= 173.4^k$$

(2) Tension control point

assume e' = 3"

$$\left(1 - \frac{h}{2d}\right) \geq \frac{e'}{d} \geq 0$$

$$\left(1 - \frac{24}{44}\right) \geq \frac{3}{22} \geq 0$$

$$0.455 \geq 0.136 \geq 0$$

$$k_u = \frac{\rho' \frac{d'}{d}\left(1 - \frac{d'}{d} - \frac{e'}{d}\right) - \rho \frac{e'}{d}}{\rho \frac{e'}{d} - \rho'\left(1 - \frac{d'}{d} - \frac{e'}{d}\right)} \qquad (3\text{-}27)$$

$$= \frac{0.0076\left(\frac{2}{22}\right)\left(1 - \frac{2}{22} - \frac{3}{22}\right) - 0.0114\left(\frac{3}{22}\right)}{0.0114\left(\frac{3}{22}\right) - 0.0076\left(1 - \frac{2}{22} - \frac{3}{22}\right)}$$

$$= \frac{-0.0010}{-0.0043}$$

$$= 0.233$$

$$f'_{su} = f_y \frac{\left(k_u + \frac{d'}{d}\right)}{(k_u + 1)} \geq -f_y \qquad (3\text{-}26)$$

$$= 48 \frac{\left(0.233 + \frac{2}{22}\right)}{(0.233 + 1)} \geq -48$$

$$= 12.6 > -48$$

$$\phi P_n = \phi(\rho f_y + \rho' f'_{su})bd \tag{3-24}$$

$$= 0.9(0.0114(48) + 0.0076(12.6))12(22)$$

$$= 152.8^k$$

$$\phi M_n = \phi(\rho f_y + \rho' f'_{su})\left[\left(1 - \frac{h}{2d}\right) - \frac{e'}{d}\right]bd^2 \tag{3-25}$$

$$= 0.9[0.0114(48) + 0.0076(12.6)]\left[\left(1 - \frac{24}{44}\right) - \frac{3}{22}\right]12(22)^2$$

$$= 0.9(0.043)(0.318)(5808) \div 12$$

$$= 89.1 \text{ k - F}$$

```
010 PROGRAM VERIFICATION
020 INVESTIGATION
030 1
040 3 48 .25
050 TENSION MEMBER
060 12 24
070 2
080 3 1 22 3.5 8.5
085 2 1 2 4 8
090 0.0 0.0
*
```

PROGRAM X0066 -- CSTR -- 713-F3-R0 086
CONCRETE STRENGTH INVESTIGATION & DESIGN

DIMENSIONS OF CONCRETE SECTION

WIDTH(B) INCHES	HEIGHT(H) INCHES
12.000	24.000

REINFORCEMENT AREAS AND POSITIONS

LAYER NO.	NO. BARS	AREA BAR	Y (IN.)	X1 (IN.)	X2 (IN.)
1	3	1.00	22.00	3.50	8.50
2	2	1.00	2.00	4.00	8.00

MATERIAL CONSTANTS

F'C = 3.000 KSI
FY = 48.000 KSI

ANALYSIS FOLLOWS ETL 1110-2-265:
STRESS BLOCK DEPTH RATIO, BM = 0.550
MAXIMUM CONCRETE STRAIN, EMAX = 0.001500
CONCRETE STRESS RATIO fc/f'c, FCR = 0.8500
PHI FOR FLEXURE, PHIF = 0.900
PHI FOR AXIAL LOAD, PHIA = 0.700

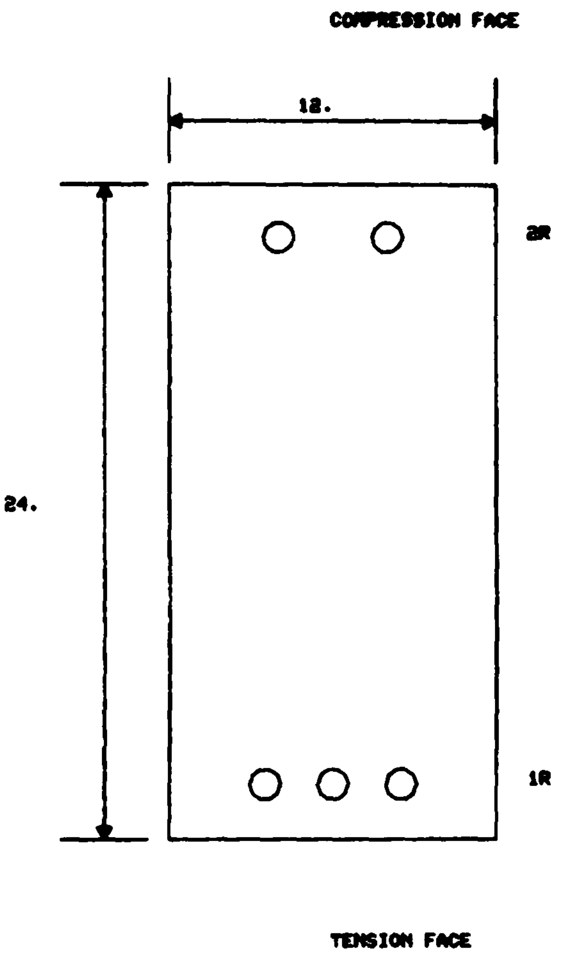


Figure 1. BASIC DATA SUMMARY

PROGRAM VERIFICATION
INVESTIGATION
TENSION MEMBER

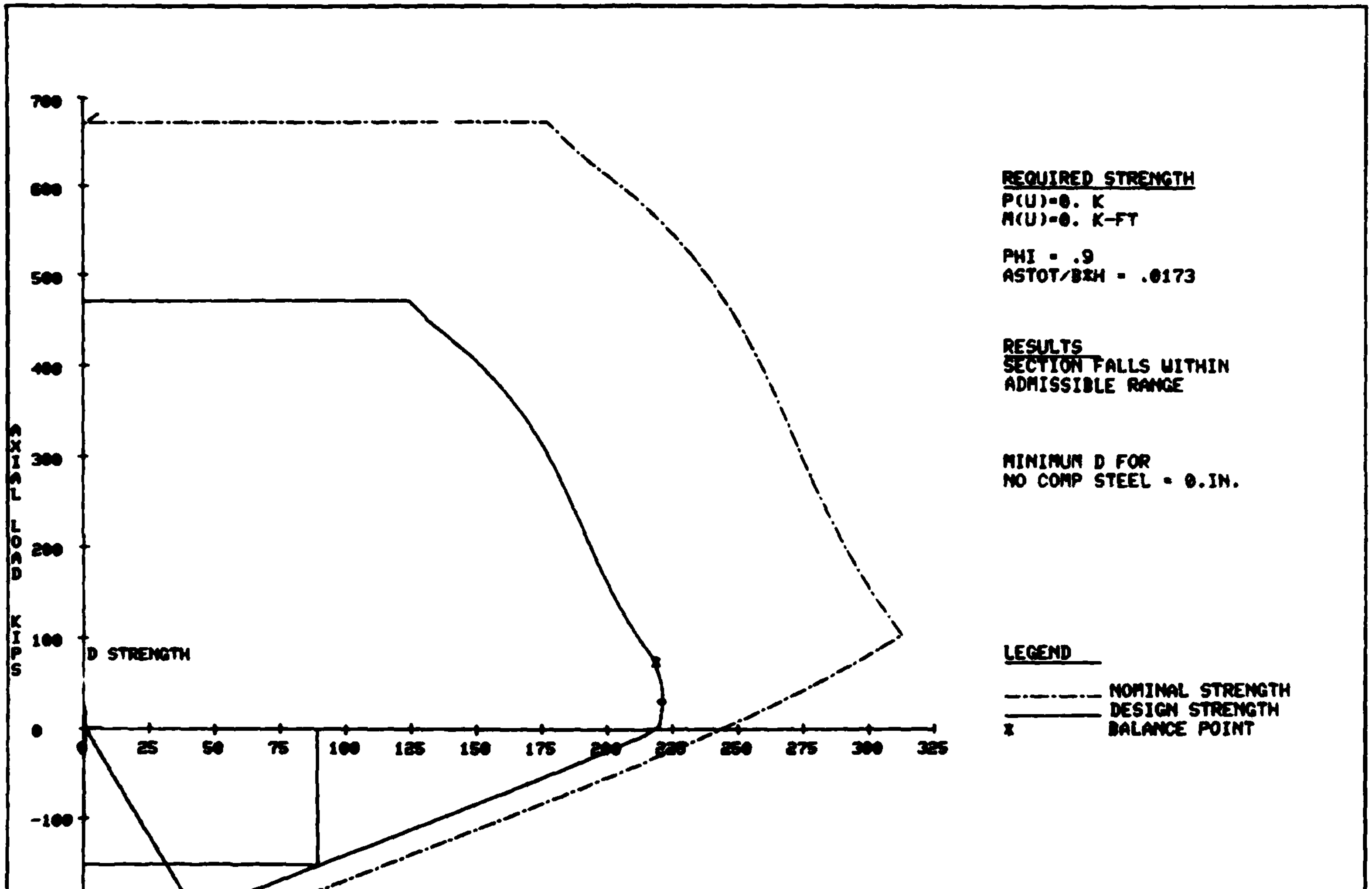
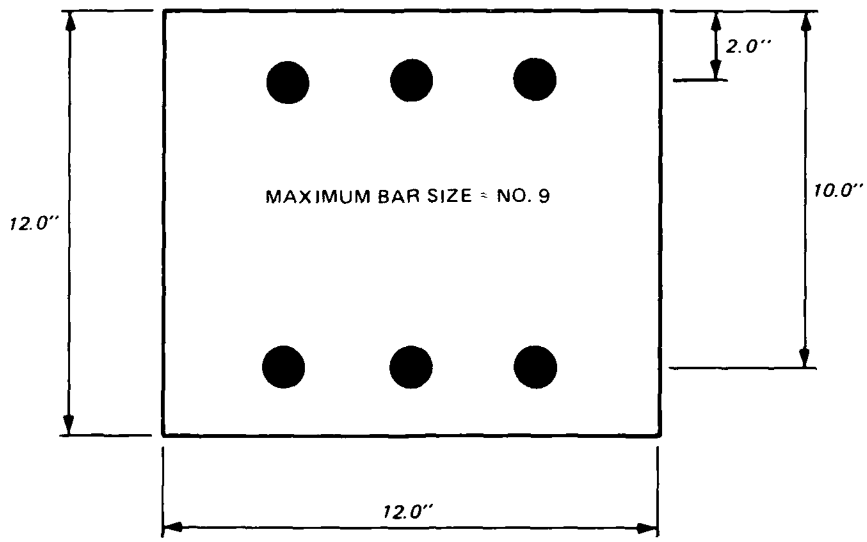


Figure 2. INTERACTION DIAGRAM

PROGRAM VERIFICATION
INVESTIGATION
TENSION MEMBER

B. Column Design

B.1 Description of problem.



Concrete cross section

B.1.1. Design Compression Control, then Investigate

$P = 100$ K

$M = 50$ K-ft

B.1.2. Design Tension Control, then Investigate

$P = 20$ K

$M = 50$ K-ft

```
010 PROGRAM VERIFICATION
020 DESIGN AND INVESTIGATION
030 2
040 3 48 .25
050 COLUMN DESIGN
060 12 12
070 2
080 3 .25 3 3 9
085 3 .25 9 3 9
090 100 50
*
```

PROGRAM X0008 -- CSTR -- 713-F3-R0 006
CONCRETE STRENGTH INVESTIGATION & DESIGN

DIMENSIONS OF CONCRETE SECTION

WIDTH(B) INCHES	HEIGHT(H) INCHES
12.000	12.000

REINFORCEMENT AREAS AND POSITIONS

LAYER NO.	NO. BARS	AREA BAR	Y (IN.)	X1 (IN.)	X2 (IN.)
1	3	1.11	3.00	3.00	9.00
2	3	1.11	9.00	3.00	9.00

MATERIAL CONSTANTS

F'C = 3.000 KSI
FY = 48.000 KSI

ANALYSIS FOLLOWS ETL 1110-2-265:
STRESS BLOCK DEPTH RATIO, BM = 0.550
MAXIMUM CONCRETE STRAIN, EMAX = 0.001500
CONCRETE STRESS RATIO f_c/f'_c, FCR = 0.8500
PHI FOR FLEXURE, PHIF = 0.900
PHI FOR AXIAL LOAD, PHIA = 0.700

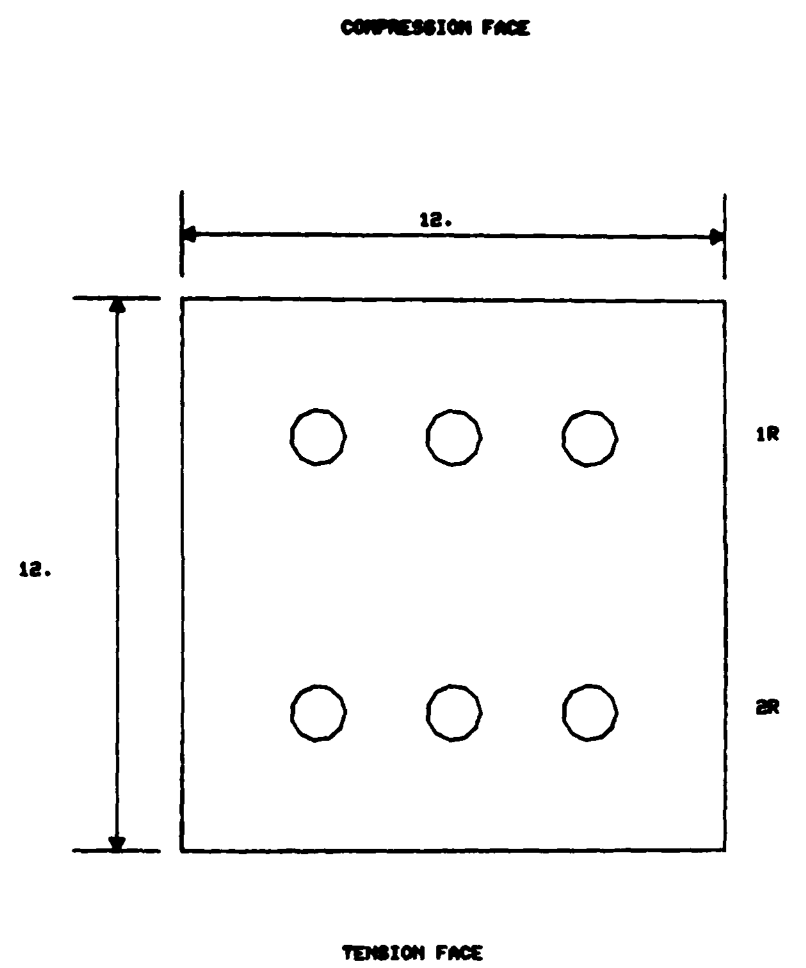


Figure 1. BASIC DATA SUMMARY

PROGRAM VERIFICATION
DESIGN AND INVESTIGATION
COLUMN DESIGN

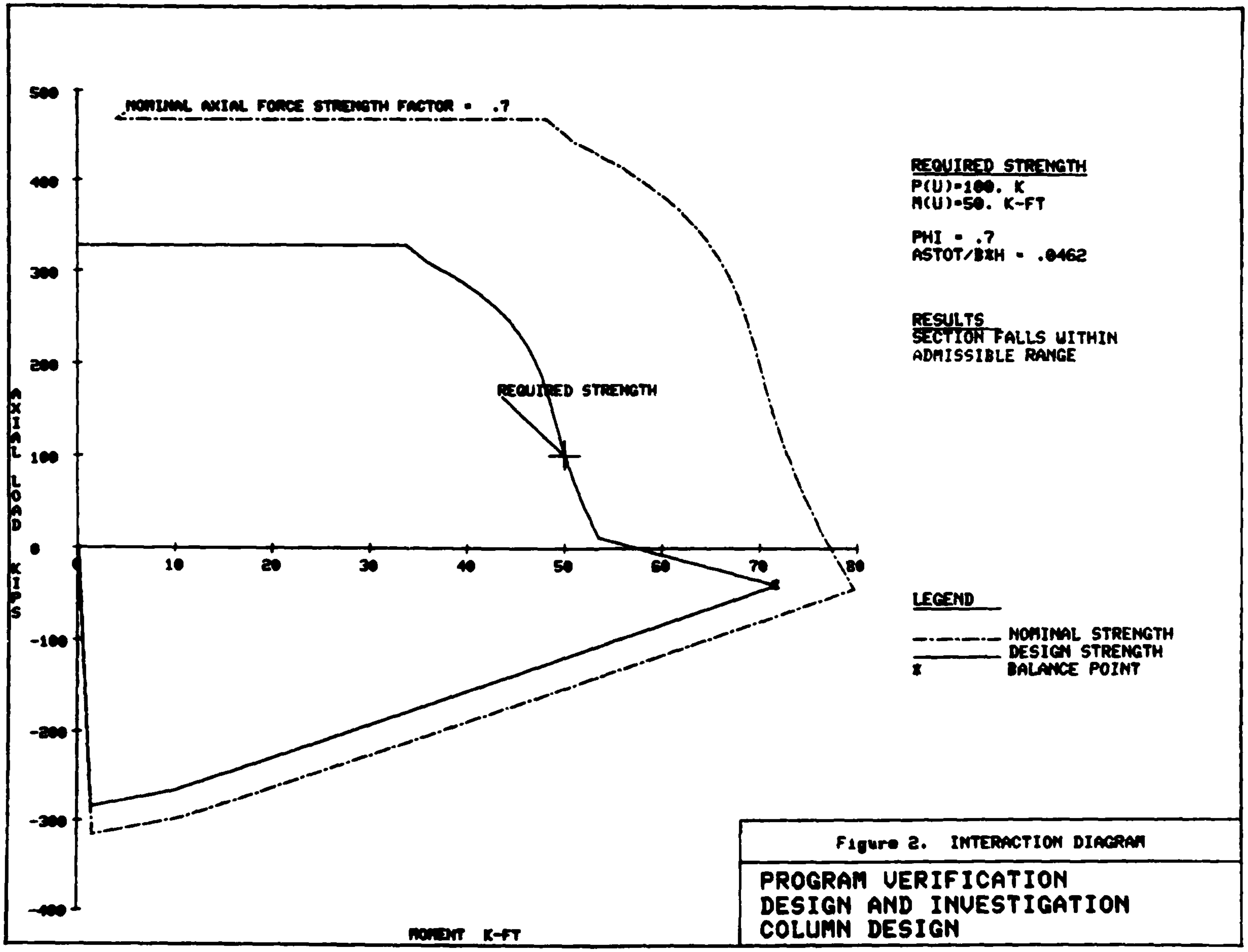


Figure 2. INTERACTION DIAGRAM

PROGRAM VERIFICATION
DESIGN AND INVESTIGATION
COLUMN DESIGN

```
010 PROGRAM VERIFICATION
020 DESIGN AND INVESTIGATION
030 1
040 3 48 .25
050 COLUMN INVESTIGATION
060 12 12
070 2
080 3 1.11 3 3 9
085 3 1.11 9 3 9
090 100 50
*
```

PROGRAM X0066 -- CSTR -- 713-F3-R0 06B
CONCRETE STRENGTH INVESTIGATION & DESIGN

DIMENSIONS OF CONCRETE SECTION

WIDTH(B) INCHES	HEIGHT(H) INCHES
12.000	12.000

REINFORCEMENT AREAS AND POSITIONS

LAYER NO.	NO. BARS	AREA BAR	Y (IN.)	X1 (IN.)	X2 (IN.)
1	3	1.11	3.00	3.00	9.00
2	3	1.11	9.00	3.00	9.00

MATERIAL CONSTANTS

F'C = 3.000 KSI
FY = 48.000 KSI

ANALYSIS FOLLOWS ETL 1110-2-265:
STRESS BLOCK DEPTH RATIO, BM = 0.550
MAXIMUM CONCRETE STRAIN, EMAX = 0.001500
CONCRETE STRESS RATIO fc/f'c, FCR = 0.8500
PHI FOR FLEXURE, PHIF = 0.900
PHI FOR AXIAL LOAD, PHIA = 0.700

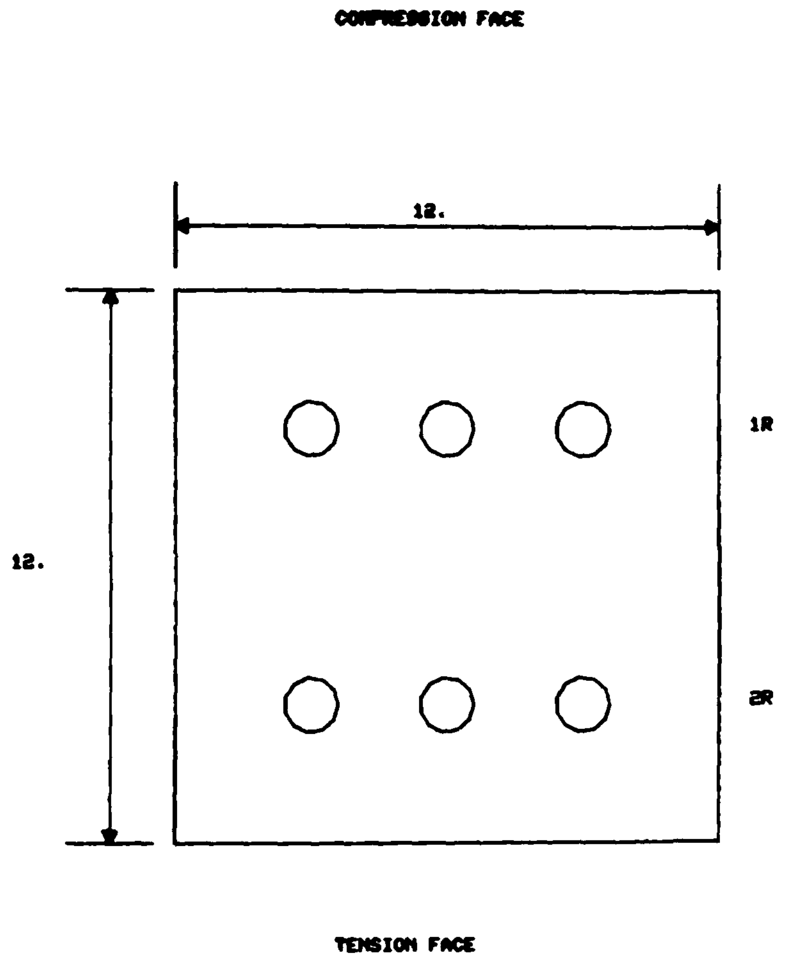
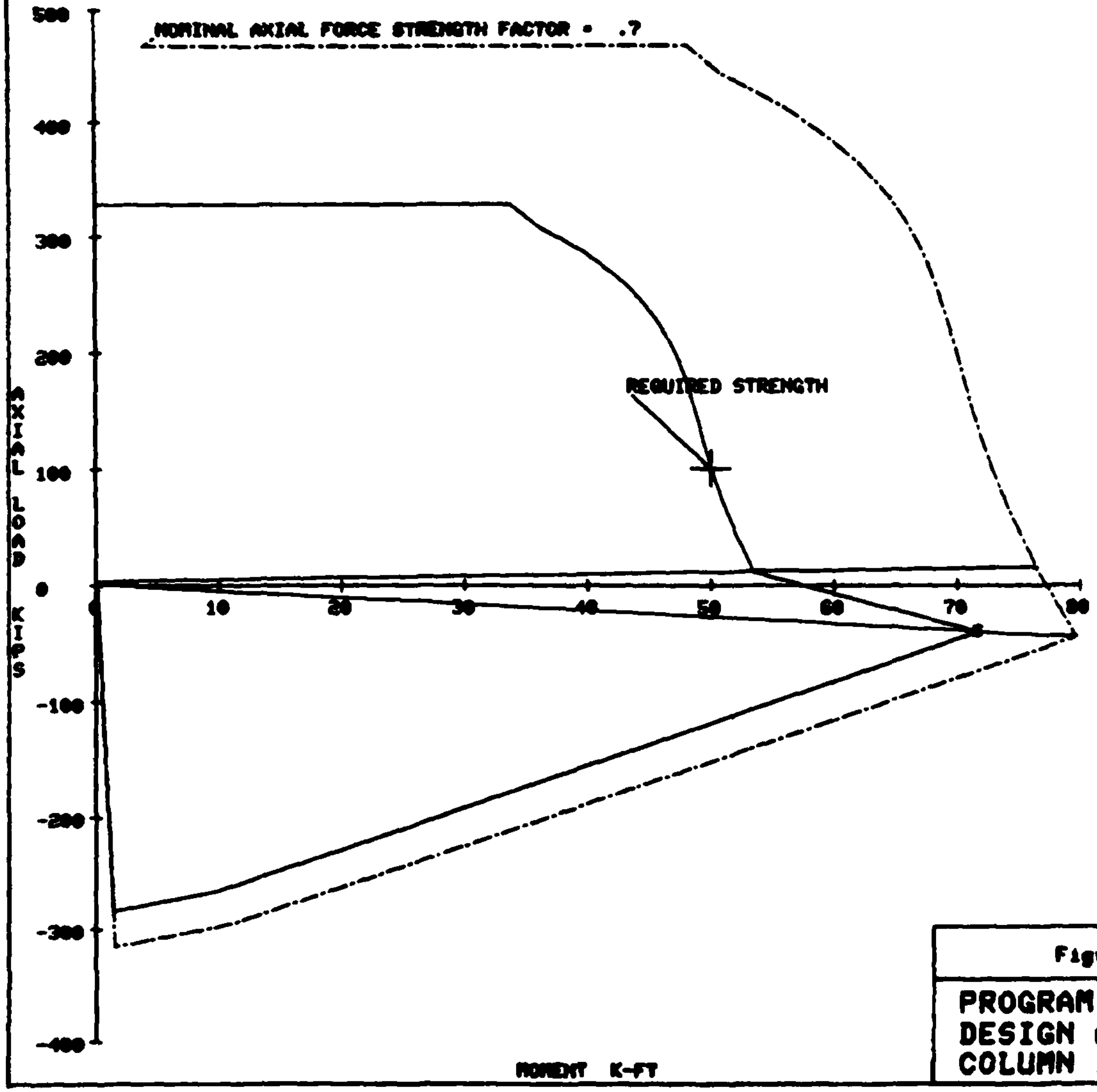


Figure 1. BASIC DATA SUMMARY

PROGRAM VERIFICATION
DESIGN AND INVESTIGATION
COLUMN INVESTIGATION



REQUIRED STRENGTH
P(U)=100. K
M(U)=50. K-FT

PHI = .7
ASTOT/B*H = .0462

RESULTS
SECTION FALLS WITHIN
ADMISSIBLE RANGE

MINIMUM D FOR
NO COMP STEEL = 24.91IN.

LEGEND

—·—·—·— NOMINAL STRENGTH
———— DESIGN STRENGTH
x BALANCE POINT

Figure 2. INTERACTION DIAGRAM

PROGRAM VERIFICATION
DESIGN AND INVESTIGATION
COLUMN INVESTIGATION

```
010 PROGRAM VERIFICATION
020 DESIGN AND INVESTIGATION
030 2
040 3 48 .25
050 COLUMN DESIGN
060 12 12
070 2
080 3 .25 3 3 9
085 3 .25 9 3 9
090 20 50
*
```

PROGRAM X0086 -- CSTR -- 713-F3-R0 086
CONCRETE STRENGTH INVESTIGATION & DESIGN

DIMENSIONS OF CONCRETE SECTION

WIDTH(B) INCHES	HEIGHT(H) INCHES
12.000	12.000

REINFORCEMENT AREAS AND POSITIONS

LAYER NO.	NO. BARS	AREA BAR	Y (IN.)	X1 (IN.)	X2 (IN.)
1	3	1.00	3.00	3.00	9.00
2	3	1.00	9.00	3.00	9.00

MATERIAL CONSTANTS

F'C = 3.000 KSI
FY = 48.000 KSI

ANALYSIS FOLLOWS ETL 1110-2-265:
STRESS BLOCK DEPTH RATIO, BR = 0.550
MAXIMUM CONCRETE STRAIN, EMAX = 0.001500
CONCRETE STRESS RATIO fc/f'c, FCR = 0.8500
PHI FOR FLEXURE, PHIF = 0.900
PHI FOR AXIAL LOAD, PHIA = 0.700

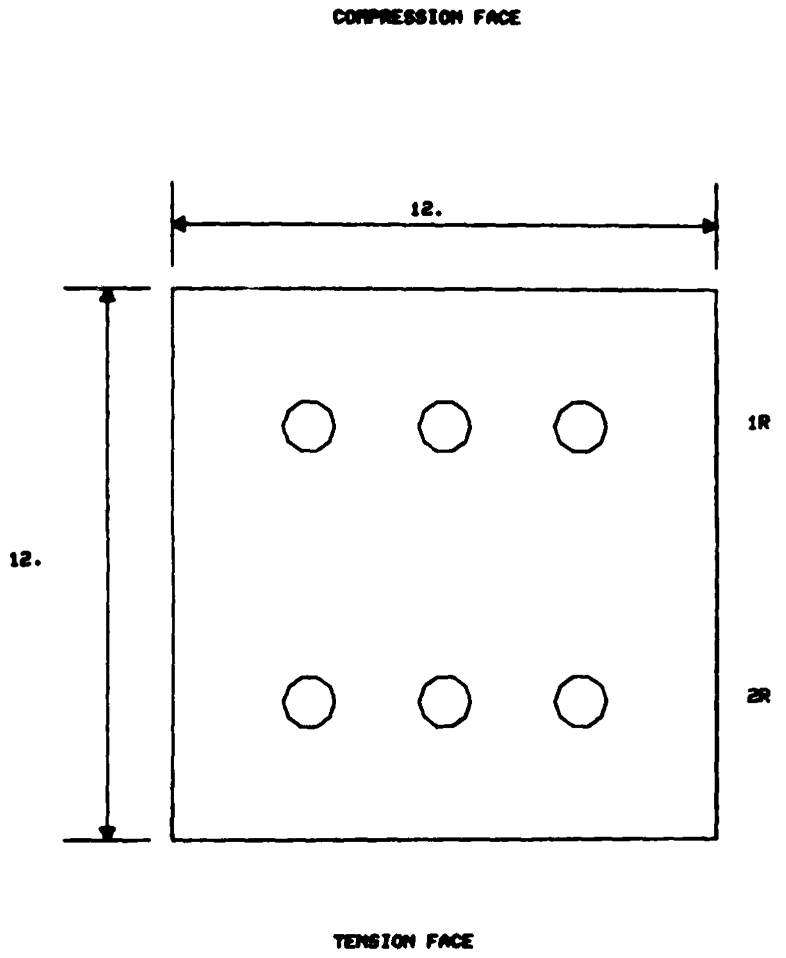


Figure 1. BASIC DATA SUMMARY

PROGRAM VERIFICATION
DESIGN AND INVESTIGATION
COLUMN DESIGN

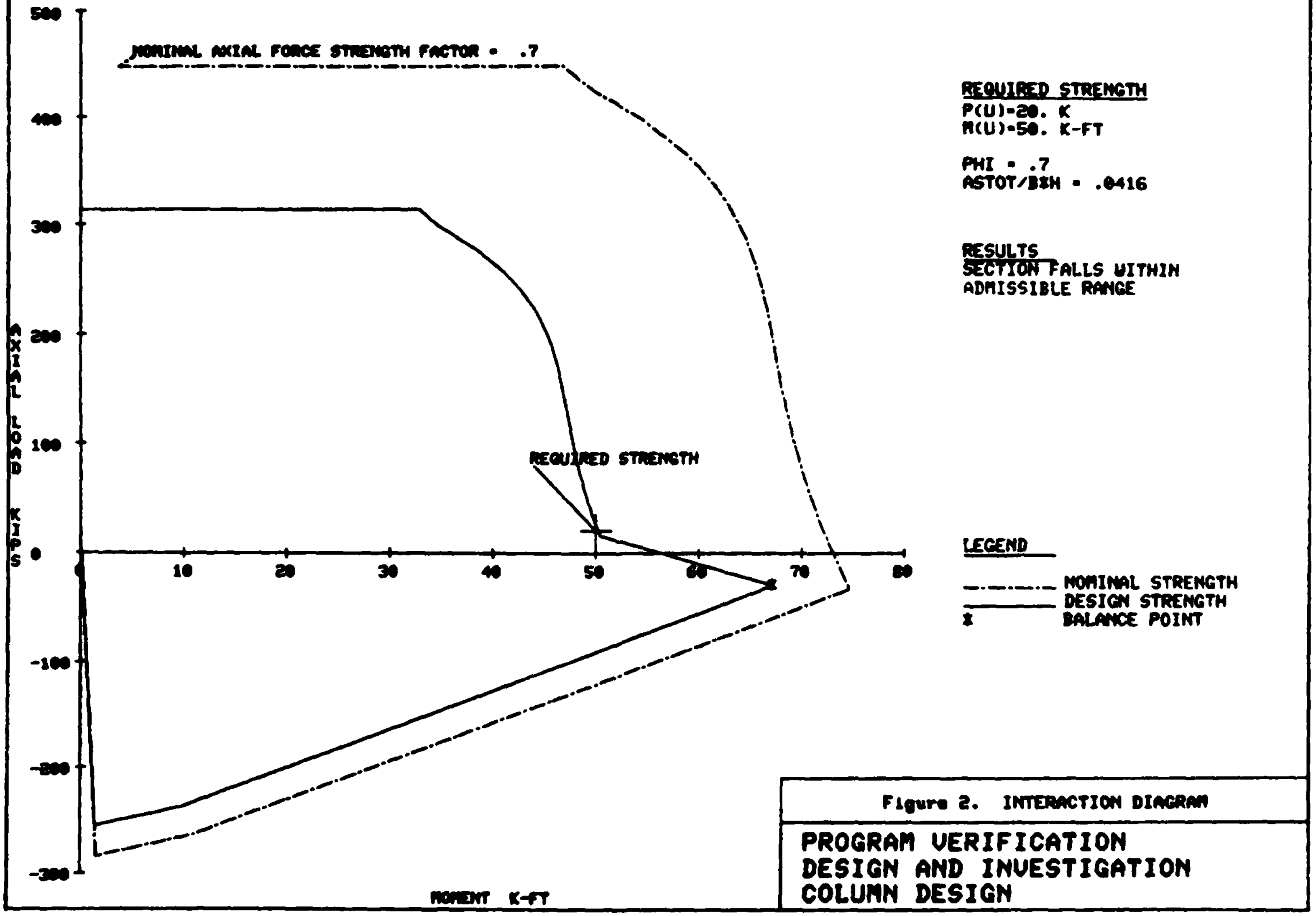


Figure 2. INTERACTION DIAGRAM

PROGRAM VERIFICATION
DESIGN AND INVESTIGATION
COLUMN DESIGN

```
010 PROGRAM VERIFICATION
020 DESIGN AND INVESTIGATION
030 1
040 3 48 .25
050 COLUMN INVESTIGATION
060 12 12
070 2
080 3 1 3 3 9
085 3 1 9 3 9
090 20 50
*
```

PROGRAM X0026 -- CSTR -- 713-F3-R0 008
CONCRETE STRENGTH INVESTIGATION & DESIGN

DIMENSIONS OF CONCRETE SECTION

WIDTH(B) INCHES	HEIGHT(H) INCHES
12.000	12.000

REINFORCEMENT AREAS AND POSITIONS

LAYER NO.	NO. BARS	AREA BAR	Y (IN.)	X1 (IN.)	X2 (IN.)
1	3	1.00	3.00	3.00	9.00
2	3	1.00	9.00	3.00	9.00

MATERIAL CONSTANTS

F'C = 3.000 KSI
FY = 48.000 KSI

ANALYSIS FOLLOWS ETL 1110-2-265:
STRESS BLOCK DEPTH RATIO, BM = 0.550
MAXIMUM CONCRETE STRAIN, EMAX = 0.001500
CONCRETE STRESS RATIO fc/f'c, FCR = 0.8500
PHI FOR FLEXURE, PHIF = 0.900
PHI FOR AXIAL LOAD, PHIA = 0.700

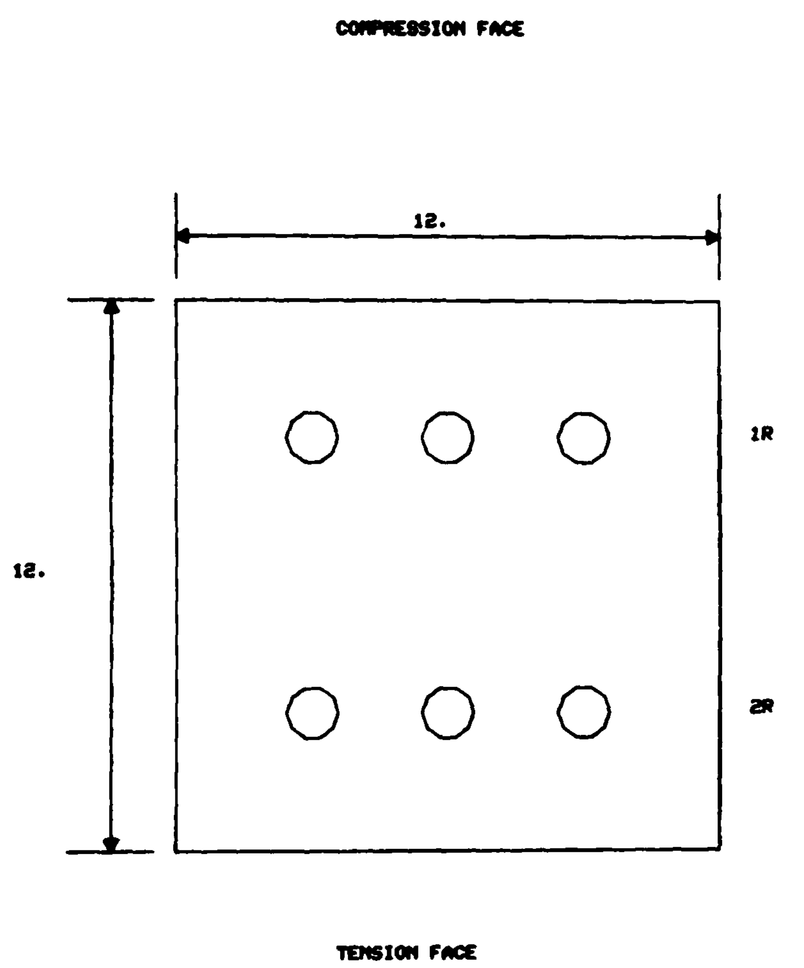
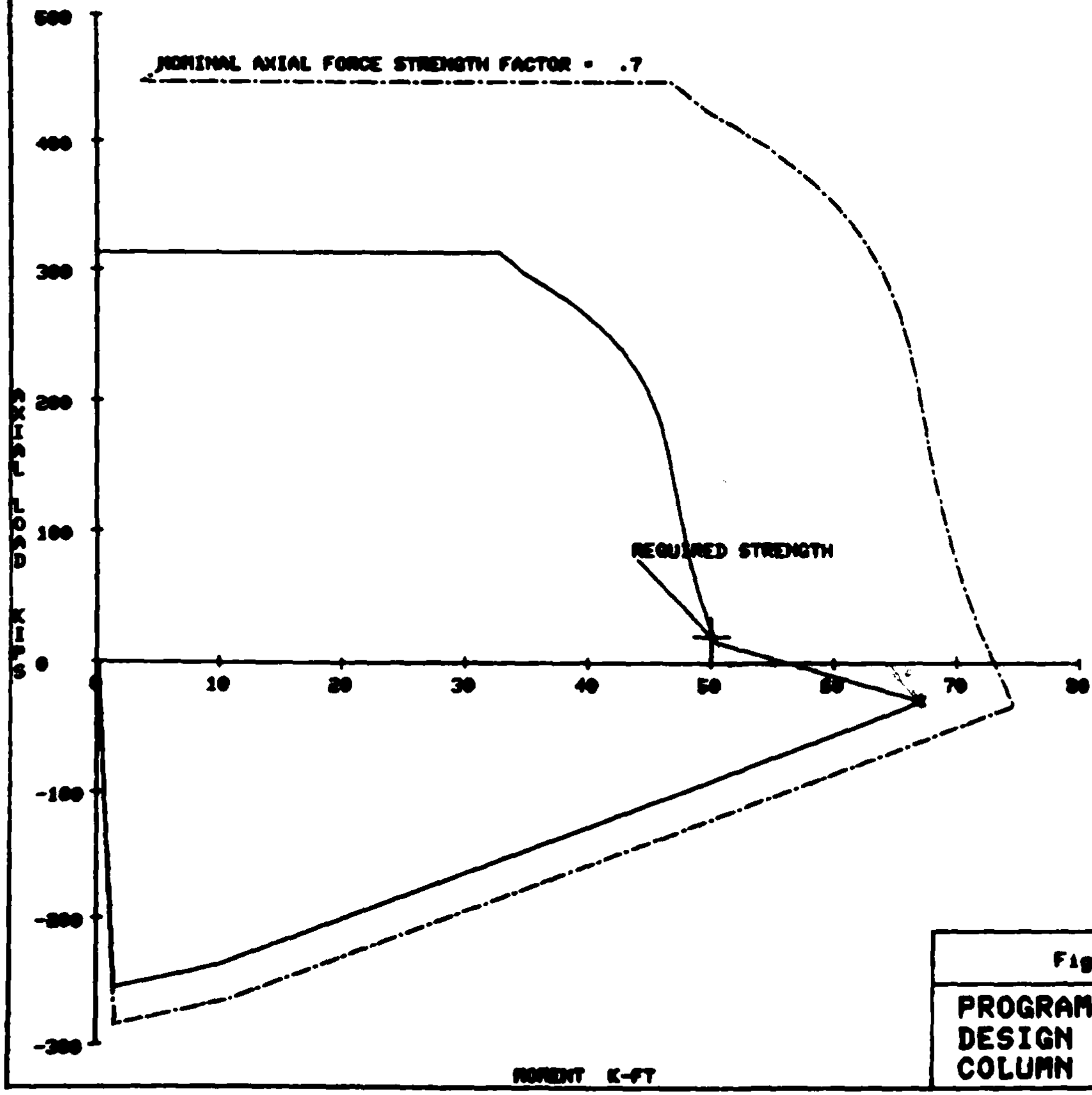


Figure 1. BASIC DATA SUMMARY

PROGRAM VERIFICATION
DESIGN AND INVESTIGATION
COLUMN INVESTIGATION



REQUIRED STRENGTH
P(U)=20. K
M(U)=50. K-FT

PHI = .7
ASTOT/B*H = .0416

RESULTS
SECTION FALLS WITHIN
ADMISSIBLE RANGE

MINIMUM D FOR
NO COMP STEEL = 16.39IN.

LEGEND
—·—·—·— NOMINAL STRENGTH
———— DESIGN STRENGTH
* BALANCE POINT

Figure 2. INTERACTION DIAGRAM

PROGRAM VERIFICATION
DESIGN AND INVESTIGATION
COLUMN INVESTIGATION

```
010 PROGRAM VERIFICATION
020 DESIGN AND INVESTIGATION
030 2
040 3 48 .25
050 COLUMN DESIGN
060 12 12
070 2
080 3 .25 3 3 9
085 3 .25 9 3 9
090 10 52
*
```

PROGRAM X0066 -- CSTR -- 713-F3-R0 060
CONCRETE STRENGTH INVESTIGATION & DESIGN

DIMENSIONS OF CONCRETE SECTION

WIDTH(B) INCHES	HEIGHT(H) INCHES
12.000	12.000

REINFORCEMENT AREAS AND POSITIONS

LAYER NO.	NO. BARS	AREA BAR	Y (IN.)	X1 (IN.)	X2 (IN.)
1	3	0.97	3.00	3.00	9.00
2	3	0.97	9.00	3.00	9.00

MATERIAL CONSTANTS

F'C = 3.000 KSI
FY = 48.000 KSI

ANALYSIS FOLLOWS ETL 1110-2-265:
STRESS BLOCK DEPTH RATIO, BM = 0.550
MAXIMUM CONCRETE STRAIN, EMAX = 0.001500
CONCRETE STRESS RATIO fc/f'c, FCR = 0.8500
PHI FOR FLEXURE, PHIF = 0.900
PHI FOR AXIAL LOAD, PHIA = 0.700

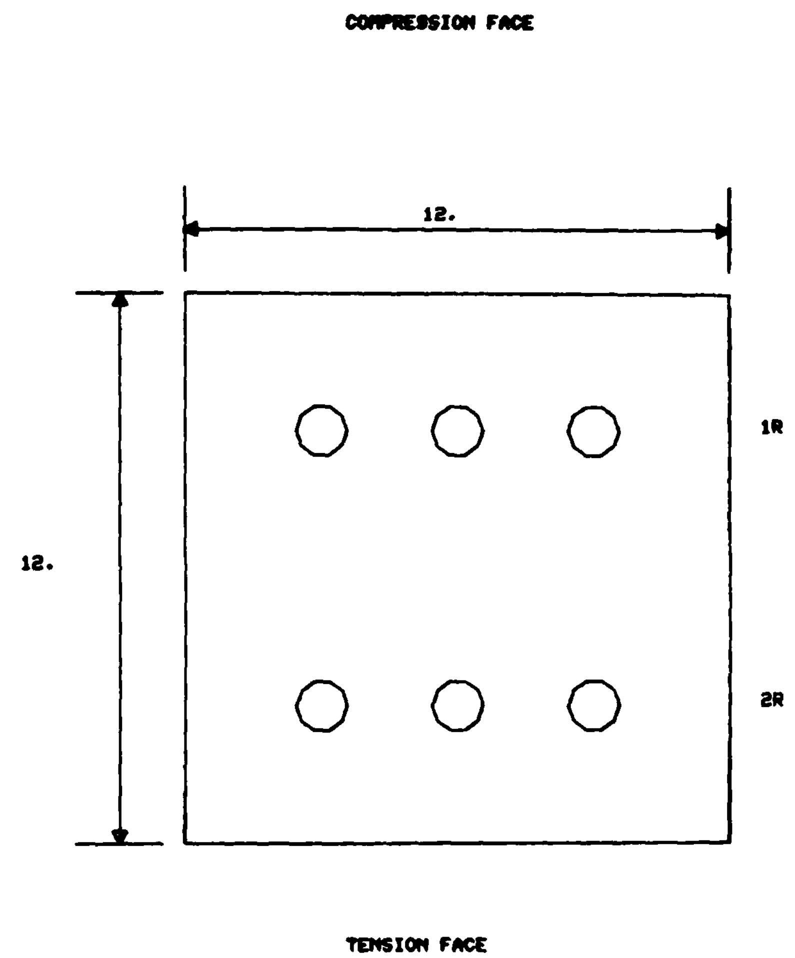


Figure 1. BASIC DATA SUMMARY

PROGRAM VERIFICATION
DESIGN AND INVESTIGATION
COLUMN DESIGN

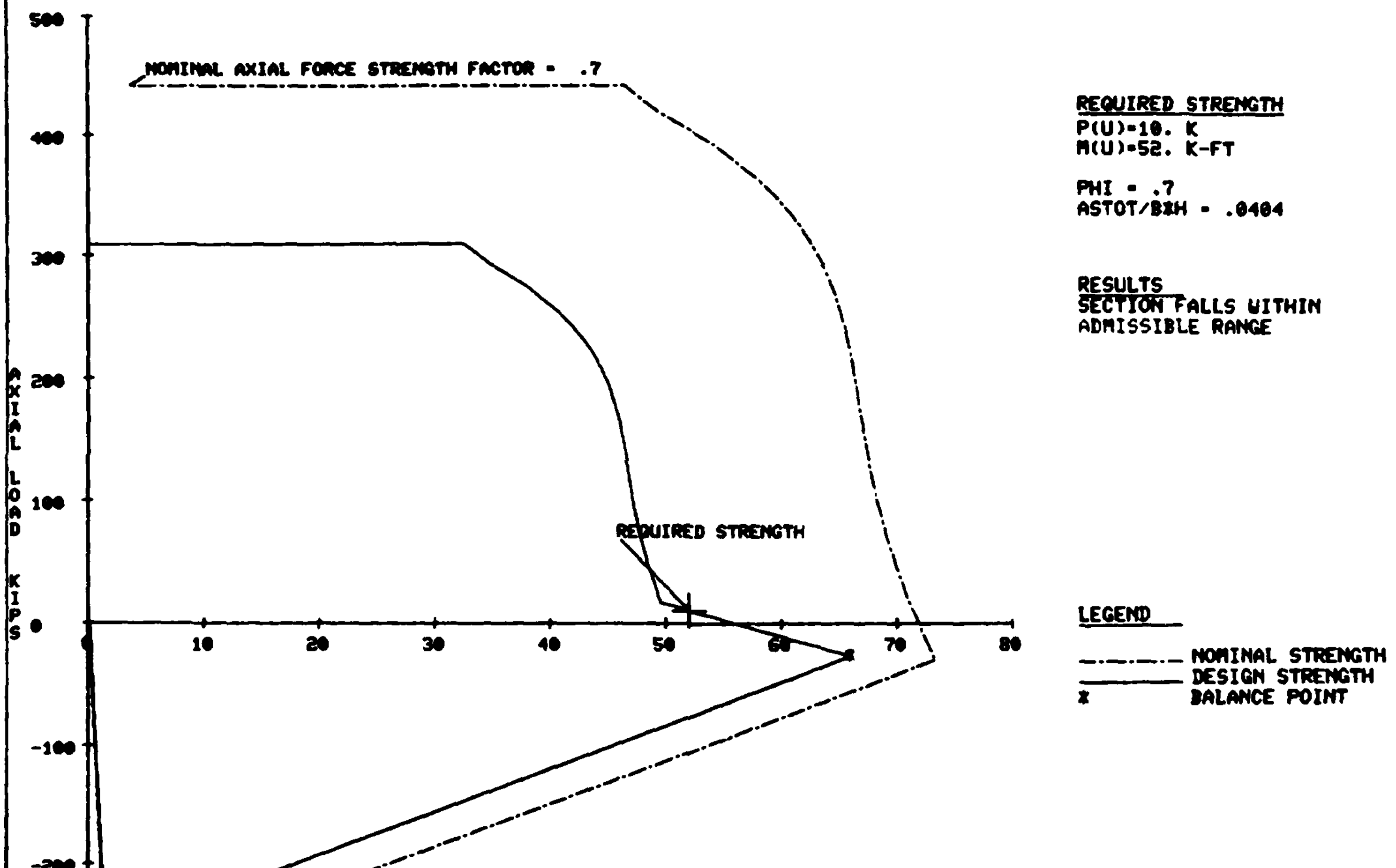


Figure 2. INTERACTION DIAGRAM

PROGRAM VERIFICATION
DESIGN AND INVESTIGATION
COLUMN DESIGN

```
010 PROGRAM VERIFICATION
020 DESIGN AND INVESTIGATION
030 1
040 3 48 .25
050 COLUMN INVESTIGATION
060 12 12
070 2
080 3 .97 3 3 9
085 3 .97 9 3 9
090 10 52
*
```

PROGRAM X0086 -- CSTR -- 713-F3-R0 006
CONCRETE STRENGTH INVESTIGATION & DESIGN

DIMENSIONS OF CONCRETE SECTION

WIDTH(B) INCHES	HEIGHT(H) INCHES
12.000	12.000

REINFORCEMENT AREAS AND POSITIONS

LAYER NO.	NO. BARS	AREA BAR	Y (IN.)	X1 (IN.)	X2 (IN.)
1	3	0.97	3.00	3.00	9.00
2	3	0.97	9.00	3.00	9.00

MATERIAL CONSTANTS

F'C = 3.000 KSI
FY = 48.000 KSI

ANALYSIS FOLLOWS ETL 1110-2-265:
STRESS BLOCK DEPTH RATIO, BM = 0.550
MAXIMUM CONCRETE STRAIN, EMAX = 0.001500
CONCRETE STRESS RATIO fc/f'c, FCR = 0.8500
PHI FOR FLEXURE, PHIF = 0.900
PHI FOR AXIAL LOAD, PHIA = 0.700

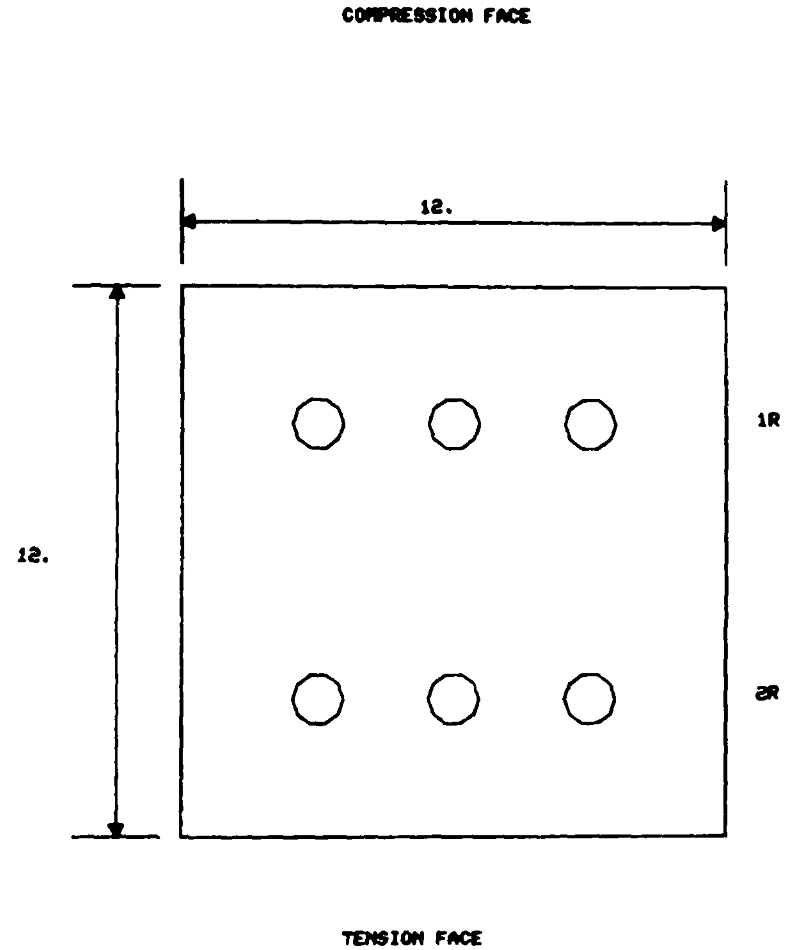


Figure 1. BASIC DATA SUMMARY

PROGRAM VERIFICATION
DESIGN AND INVESTIGATION
COLUMN INVESTIGATION

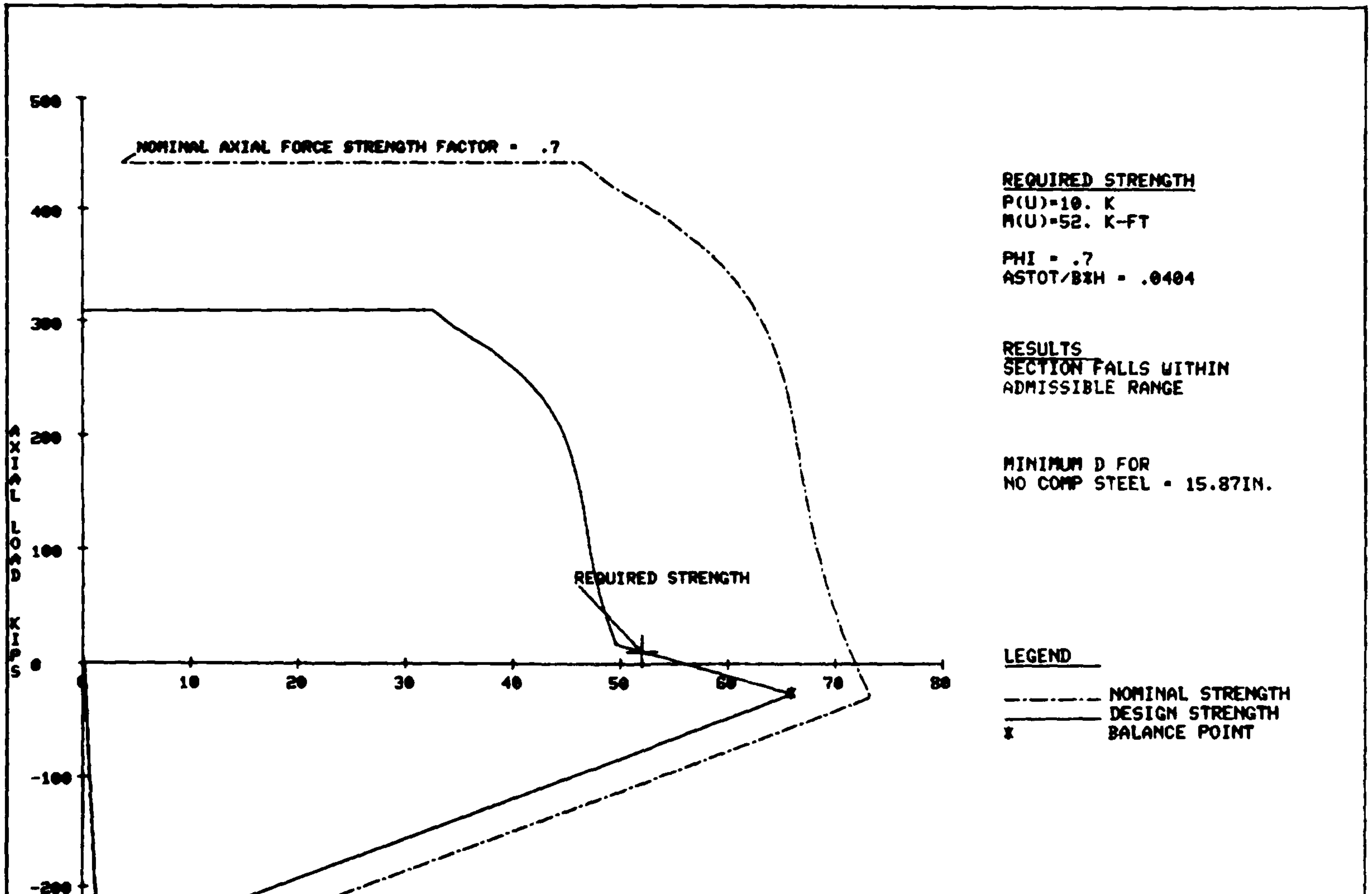


Figure 2. INTERACTION DIAGRAM

PROGRAM VERIFICATION
DESIGN AND INVESTIGATION
COLUMN INVESTIGATION

C. Beam Design (no description)

C.1. Tension control (use investigation problem)

C.2. Compression control (use investigation problem)

```
10 PROGRAM VERIFICATION
020 DESIGN
30 3
40 3 48 .85
50 SINGLY REIN.- TENSION
60 12 24
070 3 1 2 3 9 2.5
080 3 1 22 3 9 2.5
90 10 110
100 DOUBLY REIN.- TENSION
110 12 24
120 3 1 2 3 9 2.5
130 3 1 22 3 9 2.5
140 50 100
%
```

PROGRAM X0066 -- CSTR -- 713-F3-R0 068
CONCRETE STRENGTH INVESTIGATION & DESIGN

DIMENSIONS OF CONCRETE SECTION

WIDTH(B) INCHES	HEIGHT(H) INCHES
12.000	24.000

REINFORCEMENT AREAS AND POSITIONS

LAYER NO.	NO. BARS	AREA BAR	Y (IN.)	X1 (IN.)	X2 (IN.)
1	3	0.	2.00	3.00	9.00
2	3	0.47	22.00	3.00	9.00

MATERIAL CONSTANTS

F'C = 3.000 KSI
FY = 48.000 KSI

FACTOR p/p-bal, PEROB = 0.250

ANALYSIS FOLLOWS ETL 1110-2-265:
STRESS BLOCK DEPTH RATIO, BM = 0.550
MAXIMUM CONCRETE STRAIN, EMAX = 0.001500
CONCRETE STRESS RATIO fc/f'c, FCR = 0.8500
PHI FOR FLEXURE, PHIF = 0.900
PHI FOR AXIAL LOAD, PHIA = 0.700

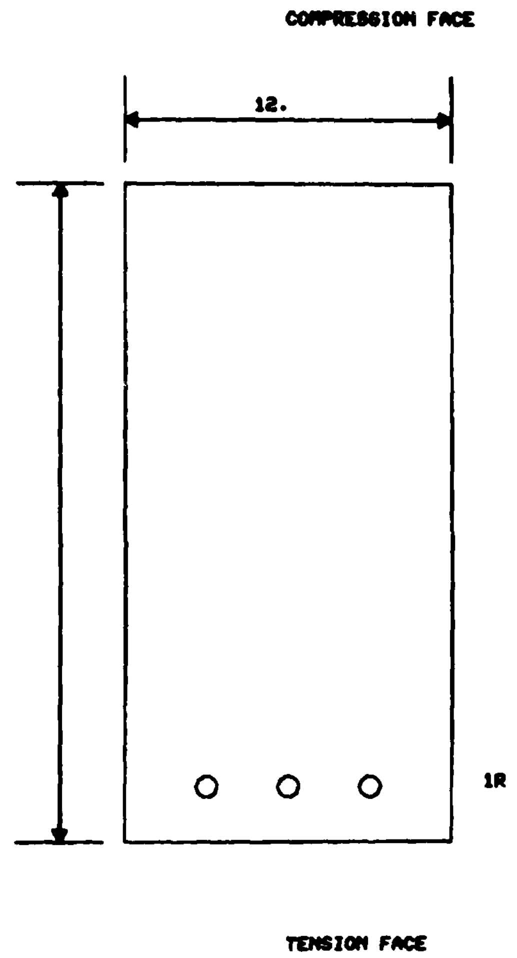
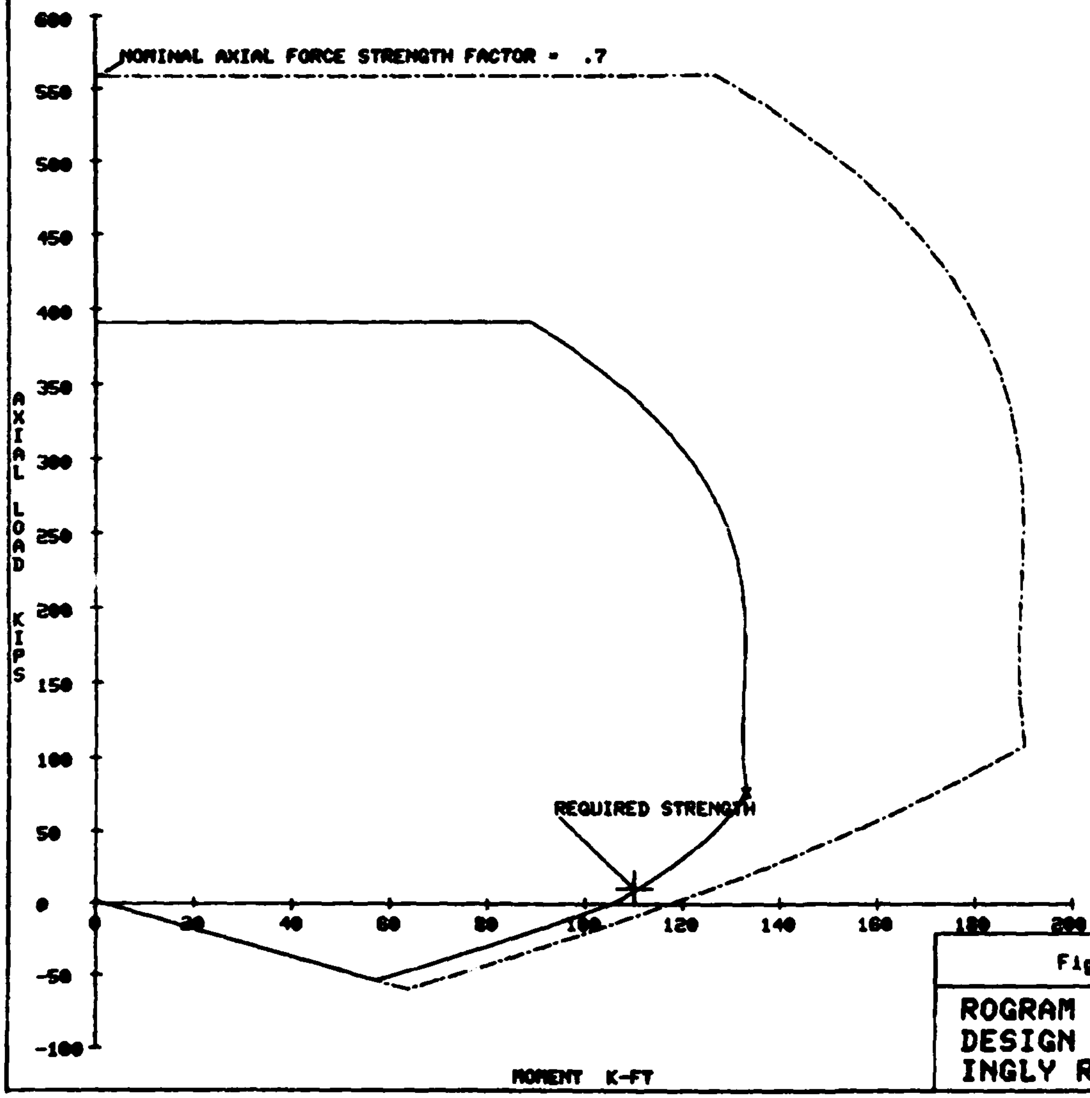


Figure 1. BASIC DATA SUMMARY

ROGRAM VERIFICATION
DESIGN
INGLY REIN.- TENSION



REQUIRED STRENGTH
P(U)=10. K
M(U)=110. K-FT

PHI = .8736
ASTOT/B*H = .0048

RESULTS
SECTION FALLS WITHIN
ADMISSIBLE RANGE
MEETS DUCTILITY REQ.

MINIMUM D FOR
NO COMP STEEL = 20.35IN.

LEGEND

—·—·—·— NOMINAL STRENGTH
———— DESIGN STRENGTH
x BALANCE POINT

Figure 2. INTERACTION DIAGRAM

ROGRAM VERIFICATION
DESIGN
INGLY REIN.- TENSION

PROGRAM X0068 -- CSTR -- 713-F3-R0 006
CONCRETE STRENGTH INVESTIGATION & DESIGN

DIMENSIONS OF CONCRETE SECTION

WIDTH(B) INCHES	HEIGHT(H) INCHES
12.000	24.000

REINFORCEMENT AREAS AND POSITIONS

LAYER NO.	NO. BARS	AREA BAR	Y (IN.)	X1 (IN.)	X2 (IN.)
1	3	0.17	2.00	3.00	9.00
2	3	0.30	22.00	3.00	9.00

MATERIAL CONSTANTS

F'C = 3.000 KSI
FY = 48.000 KSI

FACTOR p/p-bal, PEROB = 0.250

ANALYSIS FOLLOWS ETL 1110-2-265:
STRESS BLOCK DEPTH RATIO, BM = 0.550
MAXIMUM CONCRETE STRAIN, EMAX = 0.001500
CONCRETE STRESS RATIO fc/f'c, FCR = 0.8500
PHI FOR FLEXURE, PHIF = 0.900
PHI FOR AXIAL LOAD, PHIA = 0.700

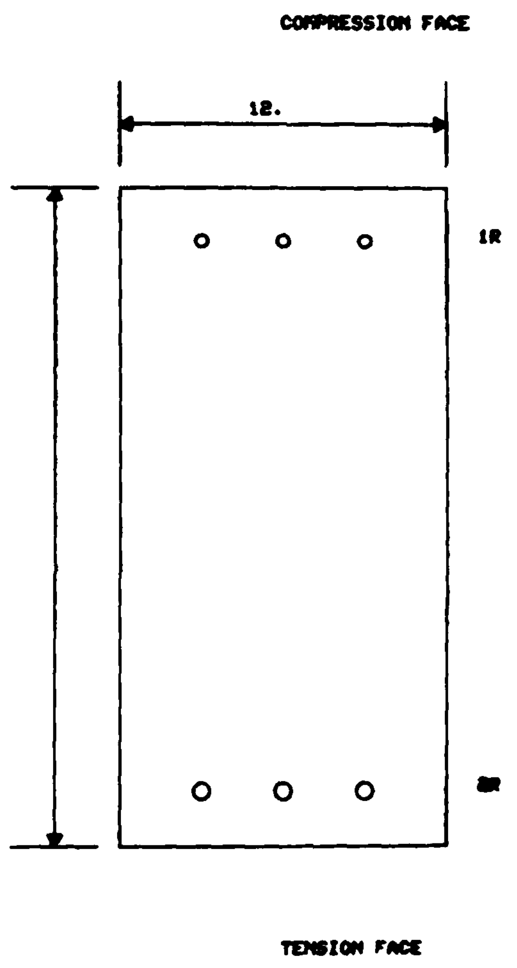


Figure 1. BASIC DATA SUMMARY

ROGRAM VERIFICATION
DESIGN
DOUBLY REIN.- TENSION

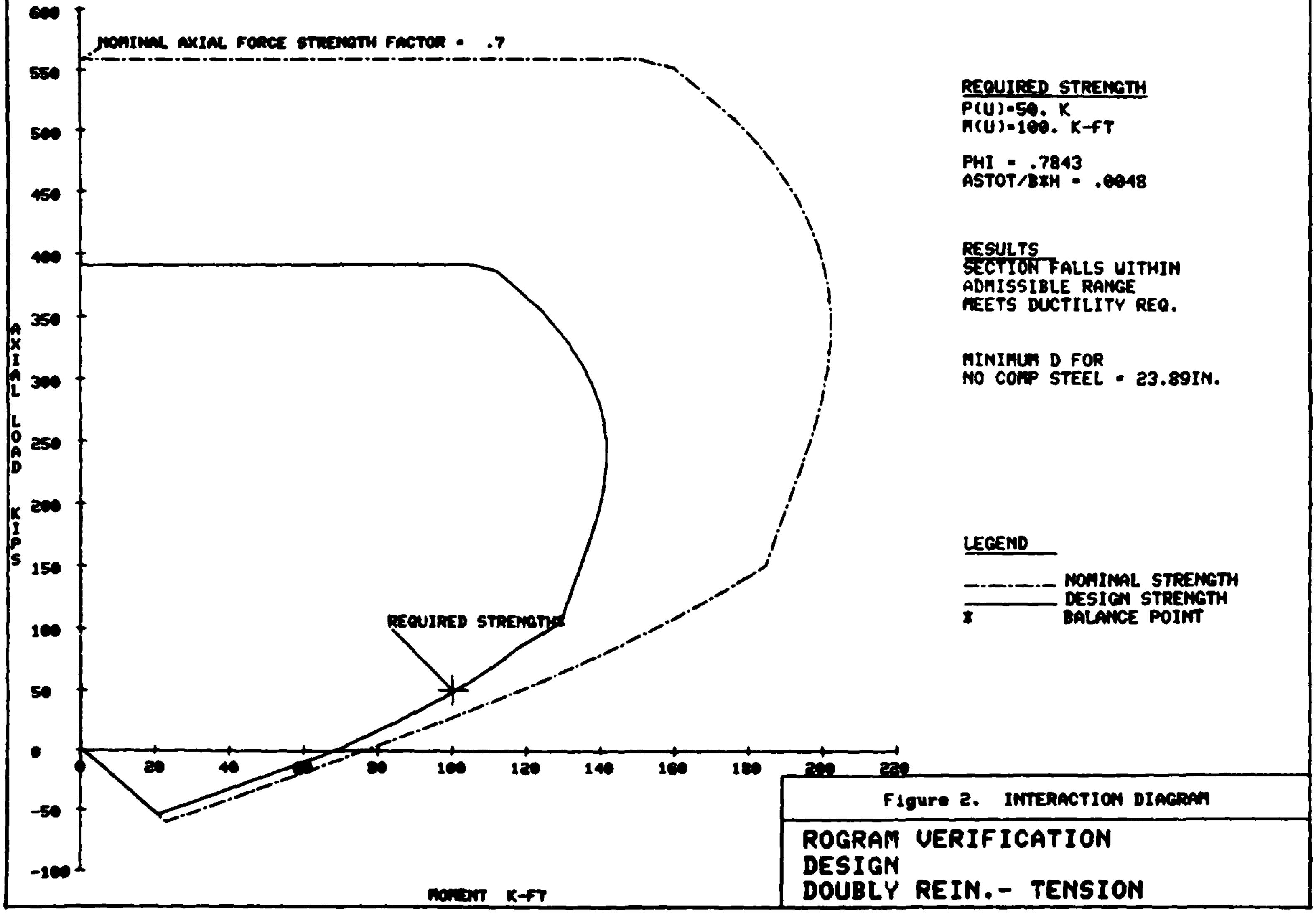


Figure 2. INTERACTION DIAGRAM

ROGRAM VERIFICATION
DESIGN
DOUBLY REIN.- TENSION

```
10 PROGRAM VERIFICATION
20 INVESTIGATION
30 1
40 3 48 .25
50 SINGLY REIN.- TENSION
60 12 24
70 1
80 3 .47 22 3 9
90 10 110
100 DOUBLY REIN.- TENSION
110 12 24
120 2
130 3 .17 2 3 9
140 3 .3 22 3 9
150 50 100
*
```

PROGRAM X0086 -- CSTR -- 713-F3-R0 086
CONCRETE STRENGTH INVESTIGATION & DESIGN

DIMENSIONS OF CONCRETE SECTION

WIDTH(B) INCHES	HEIGHT(H) INCHES
12.000	24.000

REINFORCEMENT AREAS AND POSITIONS

LAYER NO.	NO. BARS	AREA BAR	Y (IN.)	X1 (IN.)	X2 (IN.)
1	3	0.47	22.00	3.00	9.00

MATERIAL CONSTANTS

F'C = 3.000 KSI
FY = 48.000 KSI

FACTOR p/p-bal, PEROB = 0.250

ANALYSIS FOLLOWS ETL 1110-2-265:
STRESS BLOCK DEPTH RATIO, BM = 0.550
MAXIMUM CONCRETE STRAIN, EMAX = 0.001500
CONCRETE STRESS RATIO fc/f'c, FCR = 0.8500
PHI FOR FLEXURE, PHIF = 0.900
PHI FOR AXIAL LOAD, PHIA = 0.700

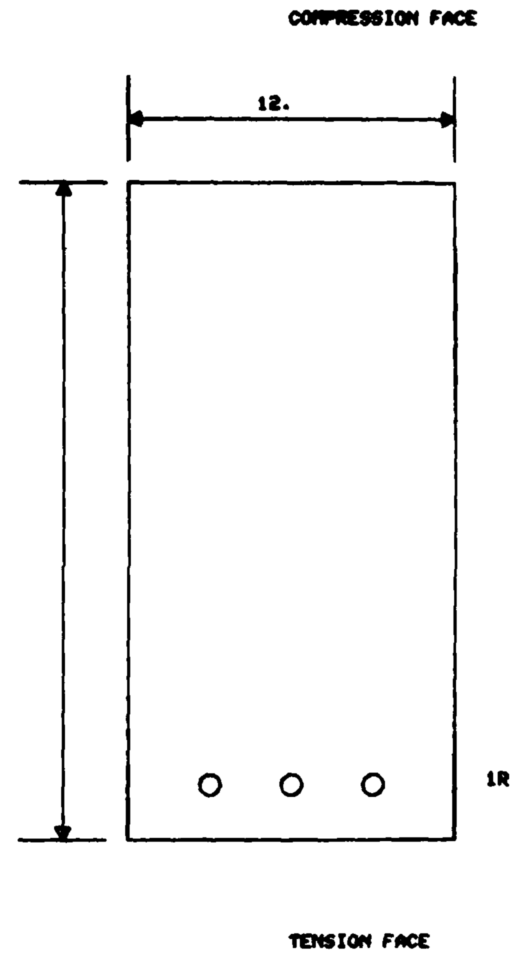


Figure 1. BASIC DATA SUMMARY

ROGRAM VERIFICATION
NVESTIGATION
INGLY REIN.- TENSION

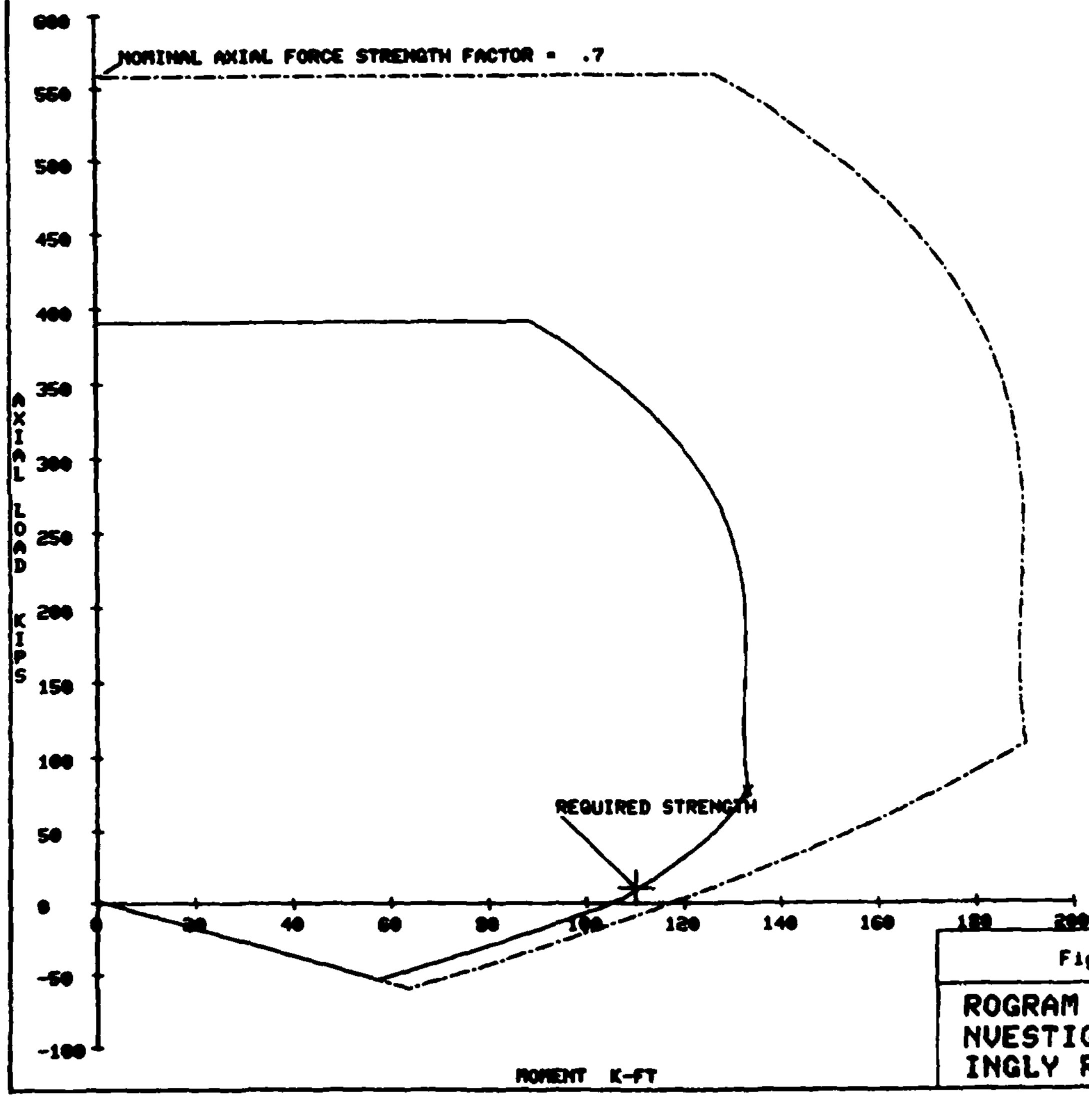


Figure 2. INTERACTION DIAGRAM

ROGRAM VERIFICATION
NVESTIGATION
INGLY REIN.- TENSION

PROGRAM X0068 -- CSTR -- 713-F3-R0 006
CONCRETE STRENGTH INVESTIGATION & DESIGN

DIMENSIONS OF CONCRETE SECTION

WIDTH(B) INCHES	HEIGHT(H) INCHES
12.000	24.000

REINFORCEMENT AREAS AND POSITIONS

LAYER NO.	NO. BARS	AREA BAR	Y (IN.)	X1 (IN.)	X2 (IN.)
1	3	0.17	2.00	3.00	9.00
2	3	0.30	22.00	3.00	9.00

MATERIAL CONSTANTS

F'C = 3.000 KSI
FY = 48.000 KSI

FACTOR p/p-bal, PEROB = 0.250

ANALYSIS FOLLOWS ETL 1110-2-265:
STRESS BLOCK DEPTH RATIO, BM = 0.550
MAXIMUM CONCRETE STRAIN, EMAX = 0.001500
CONCRETE STRESS RATIO fc/f'c, FCR = 0.8500
PHI FOR FLEXURE, PHIF = 0.900
PHI FOR AXIAL LOAD, PHIA = 0.700

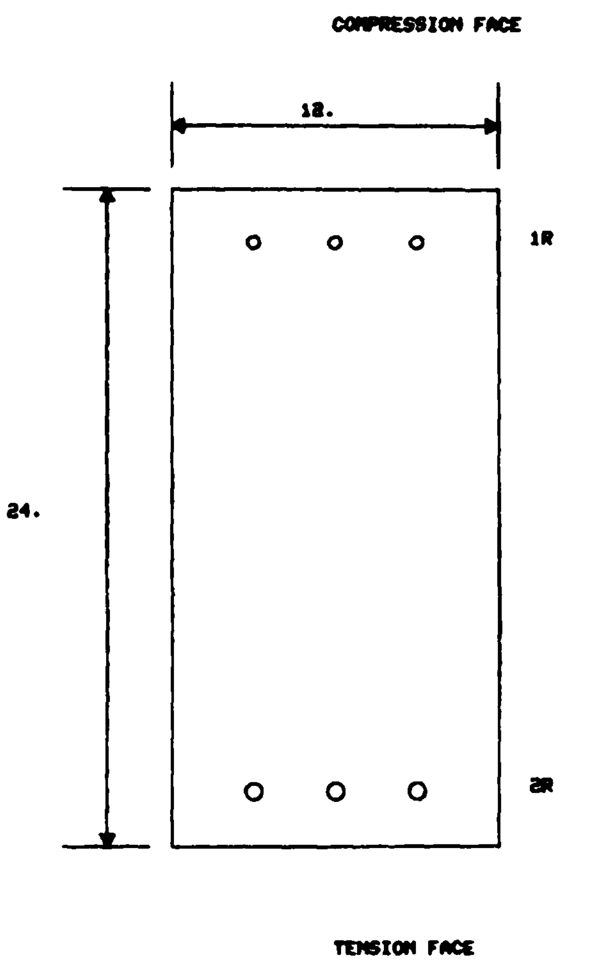


Figure 1. BASIC DATA SUMMARY

ROGRAM VERIFICATION
NVESTIGATION
DOUBLY REIN.- TENSION

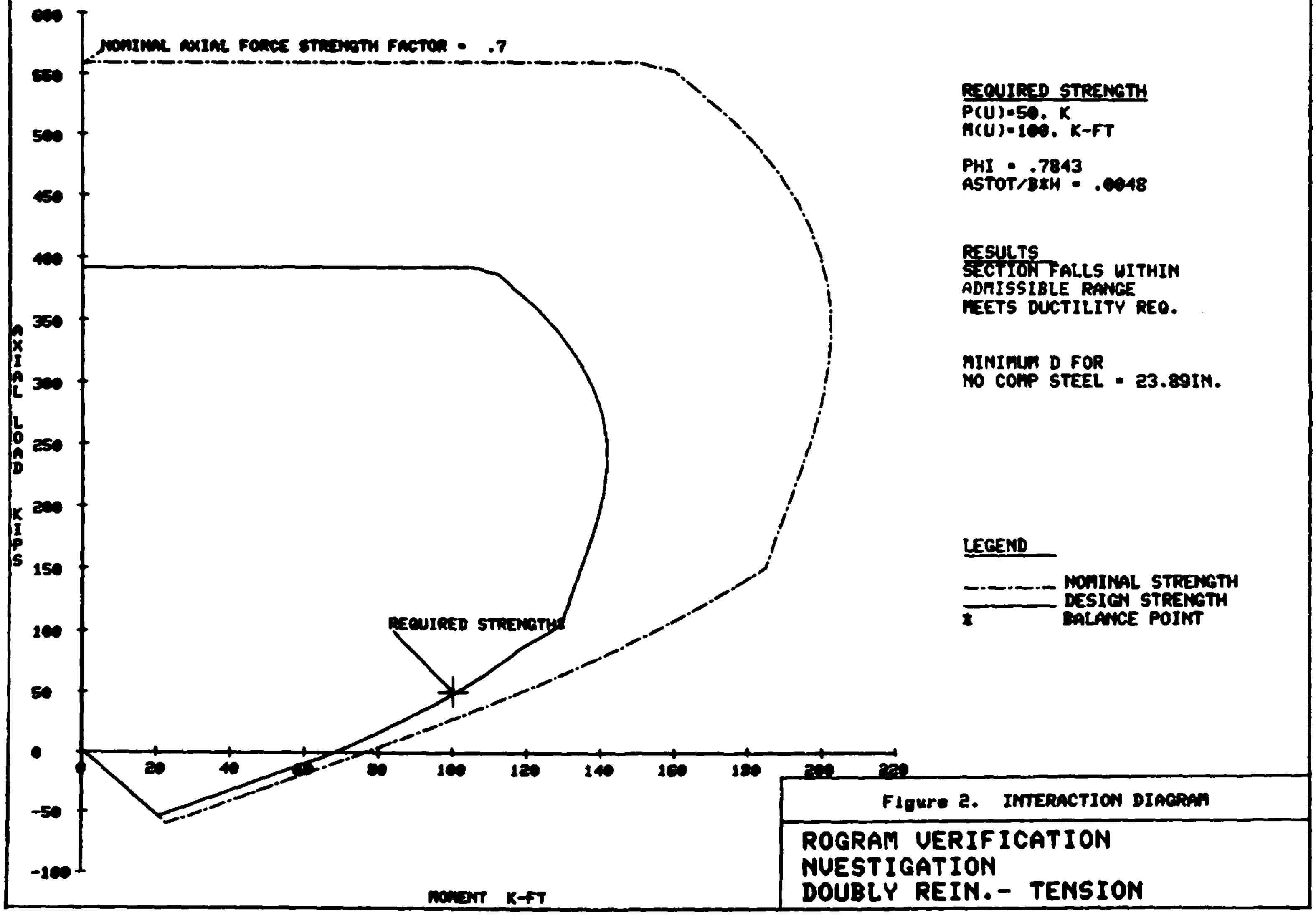


Figure 2. INTERACTION DIAGRAM

ROGRAM VERIFICATION
NVESTIGATION
DOUBLY REIN.- TENSION

D. Comparison problem

D.1. Problem description.

This problem was devised to fall on a known point in Figure 4 of Report 2 of Waterways Experiment Station (WES) Technical Report SL-80-4, "Strength Design of Reinforced Concrete Hydraulic Structures."

From Figure 4:

$f'_c = 3{,}000$ psi $\qquad F_y = 40{,}000$ psi $\qquad M_N = 0.4$

$h/d = 1.20 \qquad p = \dfrac{A_s}{bd} = 0.005 \qquad \dfrac{P_N}{bd} = 0.5$

Arbitrary Selection:

$b = 12$ in. $\qquad d = 24$ in.

Other Values: (computed by Figure 4 parameters from arbitrary values)

$h = 1.2 \times 24 \text{ in.} = 28.8 \text{ in.}$

$A_s = pbd = 0.005 \times 12 \times 24 \text{ in.} = 1.44 \text{ sq in.}$

Nominal strength values:

$M_N = 0.4 \times 12 \times 24^2 \text{ in.}^2 = 2764.8 \text{ kip-in.} = 230.4 \text{ kip-ft}$

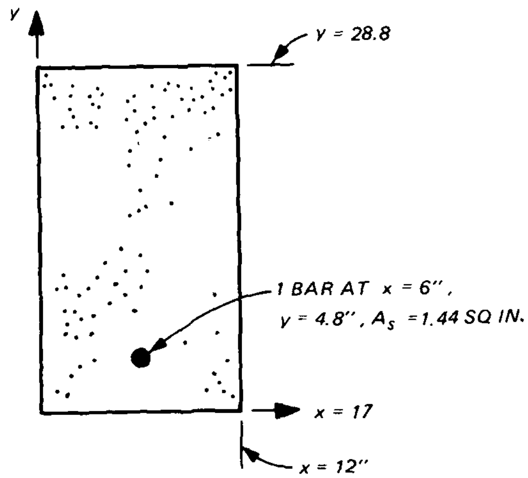
$P_N = 0.5 \times 12 \times 24 \text{ in.} = 144.0$ kips @ mid-depth

Design strength values (PHI = 0.7):

$M_N = 230.4 \times 0.7 = 161.28$ kip-ft

$P_N = 144.0 \times 0.7 = 100.8$ kip-ft

Sketch:



```
*LIST SL804F4

100 VERIFICATION PROBLEM No. 1
110 WES Tech Rept SL-80-4, Fig. 4
200 1
210 3.0  40.0  0.25
300 h/d=1.2  p=0.005  P/bd=0.5
310 12.0  28.8
400 1
410 1  1.44  24.0  6.0  5.999
500 100.8  161.28


*FRN WESLIB/CORPS/X0066,R


        10/17/83    11.656

 THE BELL WILL RING AT EACH PAUSE FOR YOU TO COPY
 WHAT YOU WANT, THEN PRESS "RETURN" TO CONTINUE.



PROGRAM X0066 -- CSIDE -- 713-F3-R0 066
CONCRETE STRENGTH INVESTIGATION & DESIGN
REV 0.1 -- SEPTEMBER 1983


ENTER NAME OF DATA FILE
=SL804F4
```

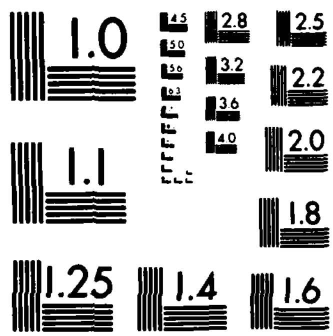
AD-A151 617 USER'S GUIDE FOR CONCRETE STRENGTH INVESTIGATION AND DESIGN (CSTR)(U) ARMY ENGINEER WATERWAYS EXPERIMENT STATION VICKSBURG MS C C HAMBY ET AL. SEP 84 2/2

UNCLASSIFIED WES-INSTRUCTION-K-84-9 F/G 11/2 NL

END

FILMED

DTIC


1.0
1.1
1.25
1.4
1.6
1.8
2.0
2.2
2.5
2.8
3.2
3.6
4.0

PROGRAM X0066 -- CSTR -- 713-F3-R0 066
CONCRETE STRENGTH INVESTIGATION & DESIGN

DIMENSIONS OF CONCRETE SECTION

WIDTH(B) INCHES	HEIGHT(H) INCHES
12.000	28.800

REINFORCEMENT AREAS AND POSITIONS

LAYER NO.	NO. BARS	AREA BAR	Y (IN.)	X1 (IN.)	X2 (IN.)
1	1	1.44	24.00	6.00	6.00

MATERIAL CONSTANTS

F'C = 3.000 KSI
FY = 40.000 KSI

FACTOR p/p-bal, PEROB = 0.250

ANALYSIS FOLLOWS ETL 1110-2-265:
STRESS BLOCK DEPTH RATIO, BM = 0.550
MAXIMUM CONCRETE STRAIN, EMAX = 0.001500
CONCRETE STRESS RATIO fc/f'c, FCR = 0.8500
PHI FOR FLEXURE, PHIF = 0.900
PHI FOR AXIAL LOAD, PHIA = 0.700

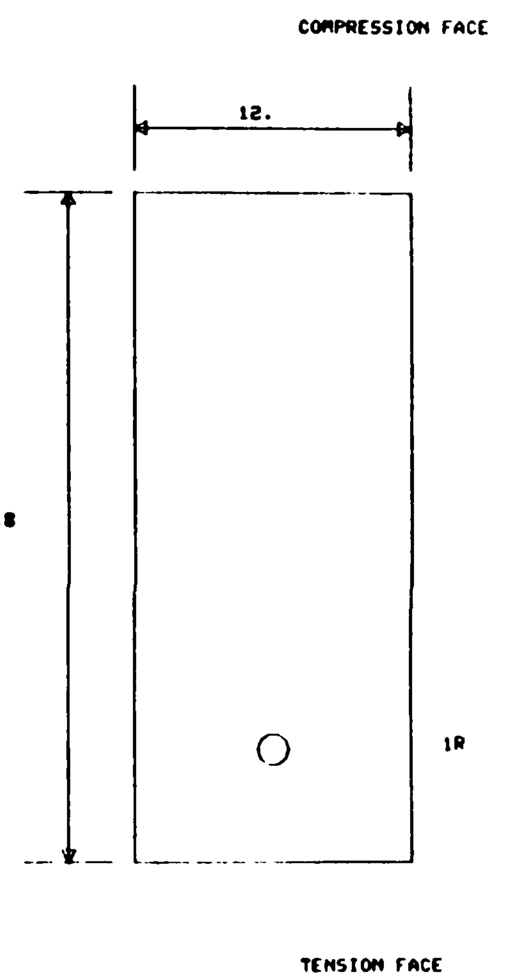
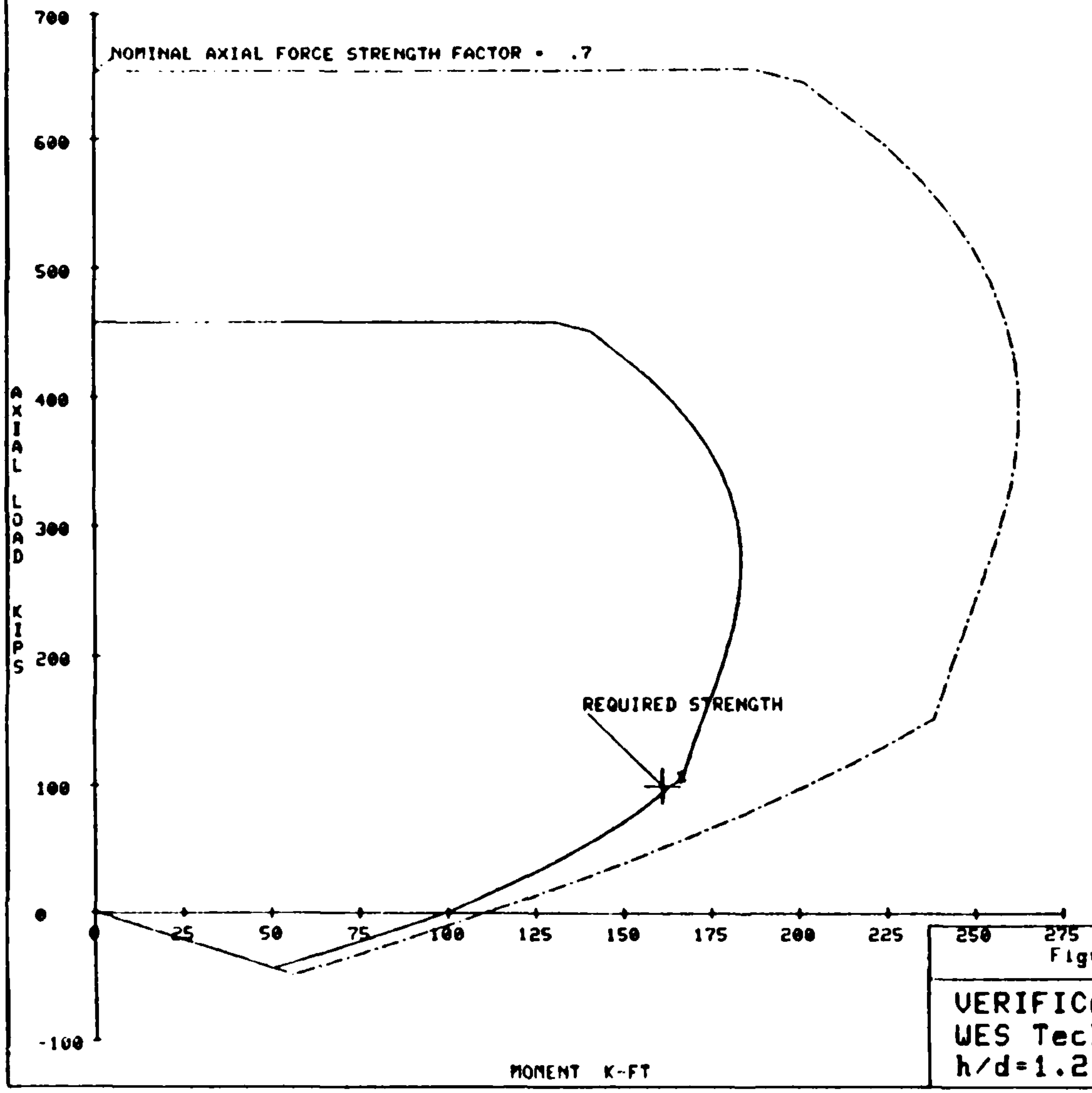


Figure 1. BASIC DATA SUMMARY

VERIFICATION PROBLEM No. 1
WES Tech Rept SL-80-4, Fig. 4
h/d=1.2 p=0.005 P/bd=0.5



REQUIRED STRENGTH
P(U)=100.8 K
M(U)=161.3 K-FT

PHI = .7056
ASTOT/B*H = .0041

RESULTS
SECTION FALLS WITHIN
ADMISSIBLE RANGE
DOES NOT MEET DUCT. REQ.

MINIMUM D FOR
NO COMP STEEL = 34.26IN.

LEGEND

— - — - — NOMINAL STRENGTH
———— DESIGN STRENGTH
* BALANCE POINT

Figure 2. INTERACTION DIAGRAM

VERIFICATION PROBLEM No. 1
WES Tech Rept SL-80-4, Fig. 4
h/d=1.2 p=0.005 P/bd=0.5

END OF DATA

*

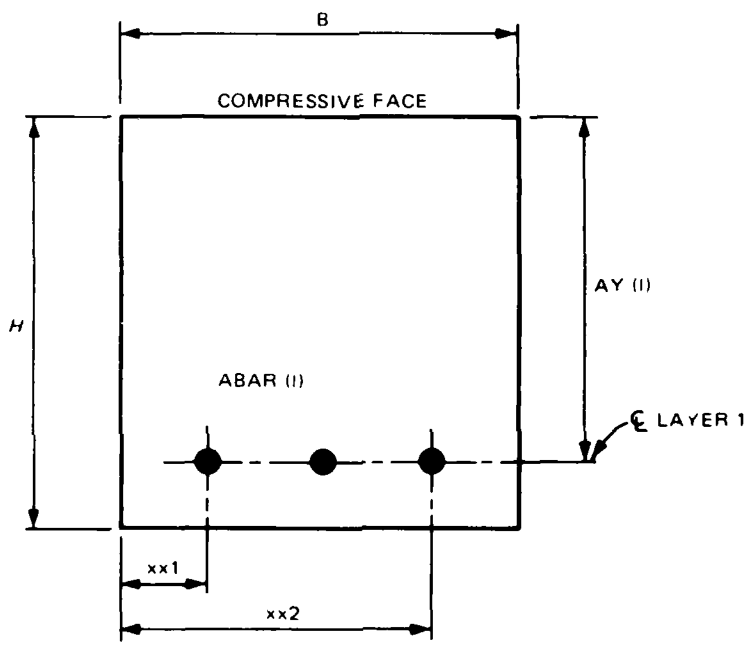
APPENDIX E: ABBREVIATED DATA FILE GUIDE

Abbreviated description
of data file preparation

1. This program will investigate or design. Paragraph 2 is concerned with investigation and design of columns, and Paragraph 3 deals with design of beams.

Investigation and
column design (MODE = 1 or 2)

2.



Note: ABAR(I) = area of one bar in layer I for investigation or ABAR(I) = min area of one bar for column design

LN JOB TITLE (30 char. max)

LN JOB TITLE (30 char. max)

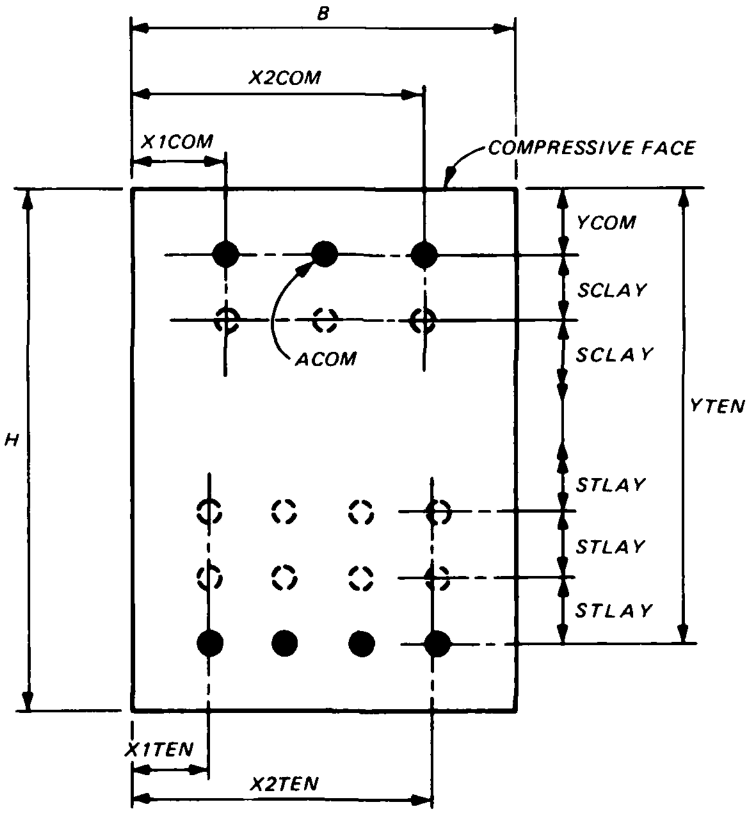
LN MODE

LN FC FY PEROB (omit PEROB for column design)

	LN	SECTION TITLE (30 char. max)
	LN	B H
Repeat for each load case	LN	NLAY
	LN	NBAR(I), ABAR(I), AY(I), XX1(I), XX2(I)
	LN	(repeat above line NLAY times, NLAY = number of layers)
	LN	PU, RMU

Beam design

3. (MODE = 3)



LN JOB TITLE (30 char. max)

LN JOB TITLE (30 char. max)

LN MODE

LN FC, FY, PEROB

Repeat for each load case	LN	SECTION TITLE (30 char. max)
	LN	B, H
	LN	NCOM, ACOM, YCOM, X1COM, X2COM, SCLAY
	LN	NTEN, ATEN, YTEN, X1TEN, X2TEN, STLAY
	LN	PU, RMU

Units

4. All dimensions are in inches, all areas are in square inches, and concrete and steel yield strengths are in kips per square inch. Forces are in kips located at B/2 and H/2 ; compression is positive. Moments are in kip-feet and include the moment caused by the axial force not actually being located at H/2 , and moments must be positive tending to cause compression in the top face in the diagram in paragraphs 2 and 3 of this appendix.

END

FILMED

4-85

DTIC